PB84-178649

Long-Term Continuous Monitor Demonstration Program: Columbus and Southern Ohio Electric Company, Conesville Unit 6

GCA Corp., Bedford, MA

Prepared for

Industrial Environmental Research Lab.
Research Triangle Park, NC

Mar 84

U.S. Department of Commerce
National Technical Information Service
NTIS

PB84-178649

EPA-600/7-84-047
March 1984

LONG-TERM CONTINUOUS MONITOR DEMONSTRATION PROGRAM: Columbus and Southern Ohio Electric Company Conesville Unit 6

by

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EPA Contract 68-02-2687, Task 10

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INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/7-84-047	2.
3. RECIPIENT'S ACCESSION NO. PB84 178649	
4. TITLE AND SUBTITLE Long-term Continuous Monitor Demonstration Program: Columbus and Southern Ohio Electric Company, Conesville Unit 6	5. REPORT DATE March 1984
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Edward F. Peduto, Jr., Timothy J. Porter, and David P. Midgley	8. PERFORMING ORGANIZATION REPORT NO. GCA-TR-83-35-G
9. PERFORMING ORGANIZATION NAME AND ADDRESS GCA/Technology Division 213 Burlington Road Bedford, Massachusetts 01730	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO. 68-02-2687, Task 10
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Industrial Environmental Research Laboratory Research Triangle Park, NC 27711	13. TYPE OF REPORT AND PERIOD COVERED Task Final; 12/79 - 3/83
	14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES IERL-RTP project officer is D. Bruce Harris, Mail Drop 62, 919/541-7807.

16. ABSTRACT The report gives results of a continuous monitoring demonstration at the Columbus and Southern Ohio Electric Company's Conesville Generating Station. The purpose of the demonstration was to determine the feasibility of the requirements for monitoring and control of SO2 emissions as specified in 40 CFR, Part 60, Subpart Da, which promulgates new source performance standards (NSPS) for new utility steam generators. A secondary objective was to adhere to the draft quality assurance requirements scheduled for promulgation as Appendix F. The report describes program activities and results of the field portion, during which data were collected for about 12 months of a 16-month period.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution Monitors Sulfur Dioxide Nitrogen Oxides Coal Combustion Utilities Boilers Quality Assurance	Pollution Control Stationary Sources	13B 14G 13A 07B 13H 21D 21B

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 113
	20. SECURITY CLASS (This page) Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

NOTICE

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ABSTRACT

A continuous monitoring demonstration program was conducted at the Columbus and Southern Ohio Electric Company (CSOE) Conesville Generating Station. The primary purpose of this program was to demonstrate the feasibility of the monitoring requirements specified in 40 CFR Part 60 Subpart Da. A secondary objective was to adhere to the draft quality assurance requirements scheduled for promulgation as Appendix F.

An assessment of system availability as a percentage of hourly unit uptime indicated an average of 78 percent and 75 percent availabilities for the SO_2 outlet emissions and control system removal efficiency reporting parameters, respectively. Availability for the NO_x system averaged 65 percent. Subpart Da availabilities (No. of valid 30-day rolling averages) were 67, 59 and 62 percent for the SO_2 emissions, efficiency and NO_x emissions reporting parameters, respectively. The reporting requirements could be met essentially 100 percent of the time due to the Method 19 Confidence Interval Reporting Method in which a confidence interval is calculated for daily data points not fulfilling minimum data capture requirements.

Evaluation of labor requirements indicate that the total average weekly level of effort was 27 hours. Of the total, 64 percent are attributable to daily operations, 23 percent to nonroutine maintenance and the remaining 13 percent for preventive maintenance.

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SECTION 1

INTRODUCTION

On June 11, 1979, the Environmental Protection Agency promulgated new source performance standards (NSPS) for new utility steam generators. These apply to units for which construction commenced after September 18, 1978. As a means of demonstrating compliance, EPA also promulgated a reference method, Method 19. This method supplies a protocol for determining the control device, sulfur input rate by either fuel analysis or continuous monitors and the final sulfur dioxide emissions to the atmosphere by continuous flue gas analysis. In addition, the sulfur removal efficiency for the control device is calculated using these measurements. This method was used to collect data for developing the current set of performance standards.

The Office of Air Quality Planning and Standards (OAQPS) with assistance from the Technical Support Staff of the Industrial Environmental Research Laboratory (IERL-RTP) initiated a program to demonstrate the feasibility of the requirements for monitoring and control of SO_2 emissions. This program focused on those sources subject to the New Source Performance Standards (NSPS) specified in 40 CFR 60 Subpart Da.

GCA/Technology Division was contracted to participate in the portion of the overall program associated with the measurement of gaseous emissions. The primary objective of the program was to demonstrate the feasibility of the monitoring requirements specified in Subpart Da. A secondary objective was the development of background and support data for future quality assurance regulations. The study involved a planning and procurement stage, a 1-year field demonstration phase and a final evaluation of the data. Approximately 12 months of data were collected during the field portion of the program over a 16 month period.

GENERAL PROGRAM APPROACH

The approach simulated the activities involved in preparing for and complying with the Subpart Da requirements. To fulfill these requirements, the utility must prepare a monitoring system specification, procure, install and certify the system and finally operate the system. Subsequently, the data are reported according to the Subpart Da specifications.

In fulfillment of the program goals, GCA conducted the program in four distinct phases as listed below:

- Phase I--Project Planning, Test Site Selection and System Specification.
- Phase II--Continuous Emissions Monitoring System (CEMS) Procurement, Installation, and Certification.
- Phase III--One-Year Field Demonstration.
- Phase IV--Data Evaluation.

During Phase I, a number of prospective utility sites were surveyed and considered as possible test locations. Since no sources subject to Subpart Da were operational at the onset of this project, only newer operational facilities subject to Subpart D specifications were considered. The test site selection criteria also included a unit firing a high-sulfur fuel source and equipped with a multimodule, wet, flue gas desulfurization system.

Based on the unit configuration of the selected facility, GCA prepared a monitoring system specification and solicited a bid from a commerical CEM vendor. At the same time, GCA prepared a competitive design for consideration by EPA. The EPA selection committee chose the commercially-available system in order to more closely simulate the activities associated with the utility procurement process.

Phase II began when GCA purchased the system from KVB, Inc. of Irvine, California and contracted with a local firm for site preparations and CEM installation. Following the installation, a startup and troubleshooting phase ensued in which the system was operated and debugged. Shortly thereafter, the system was certified according to proposed Appendix B "Specifications Tests 2 and 3" as specified in the October 10, 1979 Federal Register.

Phase III was initiated after the successful completion of the certifications tests. This phase involved:

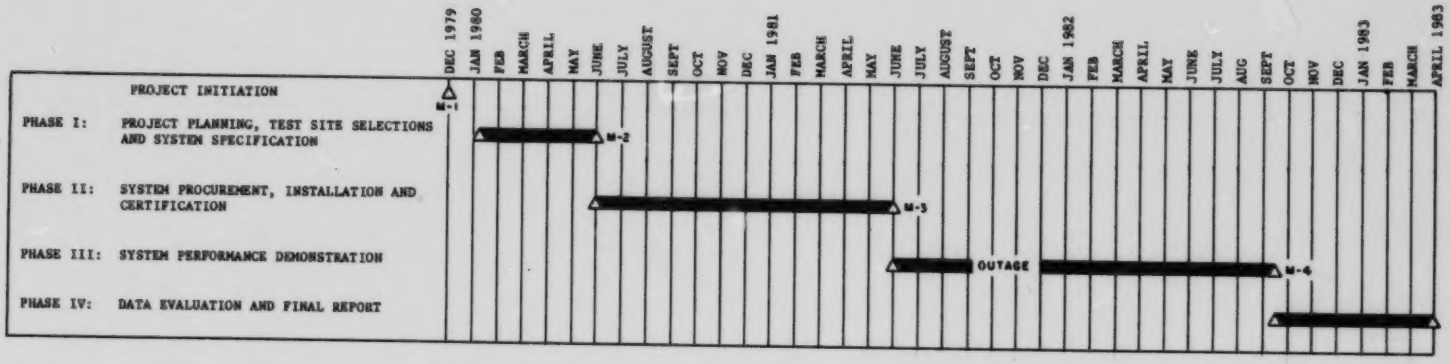
- Routine operation according to Method 19 and EPA Quality Assurance Protocols.
- Reporting consistent with Subpart Da requirements.
- Data Collection and Quality Assurance activities for assessing the monitoring economics and system performance.

Routine activities were conducted on a daily basis by an onsite technician. Additional data were collected during quarterly quality assurance and stratification tests.

At the conclusion of the test phase, all data were assembled and evaluated. The evaluation involved an assessment of CEMS availability and data capture, the economic requirements which pertain primarily to procurement, and operation and monitoring system performance. The latter topic, system performance, is discussed in reference to 40 CFR 60, Appendix B specifications and EPA Quality Assurance Protocols.

GENERAL PROGRAM SCHEDULE

The realized program schedule is shown in Figure 1. Originally the Phase III tests were scheduled for completion during June 1981. Because of a longer than anticipated procurement phase and unit outages which resulted during the demonstration phase, the overall program duration was extended to a total of 3 years. With these extensions, 12 months of operation were achieved over a time span of 16 months. During 4 of the 16 months, the generating unit was offline.



Milestone	Description	Date
M-1	Project Initiation	December 1, 1979
M-2	Phase I: Project Planning, Test Site Selection and System Specifications	May 30, 1980
M-3	Phase II: System Procurement, Installation and Certification	May 30, 1981
M-4	Phase III: System Performance Demonstration	September 15, 1982
M-5	Phase IV: Data Evaluation and Final Report	March 30, 1983

Figure 1. Realized program schedule.

SECTION 2

EXECUTIVE SUMMARY

The continuous monitoring program was conducted at the Columbus and Southern Ohio Electric Company Conesville Generating Station. Conesville Unit 6 was selected as a representative test facility since a high-sulfur fuel is fired and sulfur dioxide emissions are controlled using a wet, limestone, flue gas desulfurization system. Although the unit is not subject to Subpart Da, the duct arrangements and flue gas treatment systems associated with the facility are typical of monitoring situations and problems encountered at facilities subject to Subpart Da.

Unit 6 is rated at a gross generation capacity of 411 megawatts (MWE) and is equipped with a Combustion Engineering low-NO_x boiler. Bituminous coal with a sulfur content of 4.7 percent, an ash content of 15 to 17 percent, and a heating value of 10,000 Btu/lb is the fuel source. With this fuel, sulfur dioxide input levels to the scrubber system are typically on the order of 3470 ng/J (8 lbs/10^6 Btu). Particulate matter is controlled with a dual parallel module, cold-sided, electrostatic precipitator. Exhaust gases exiting the precipitator are directed through a UOP Air Correction Division, wet, thiosorbic lime, scrubber system. The system consists of two, 50 percent of load, spray towers with free floating balls. Although the scrubber system is designed to treat the total boiler effluent, a portion of untreated flue gas is normally bypassed and used for reheat purposes. Gases exiting the scrubber modules and bypass duct are subsequently combined through a common plenum and emitted to the atmosphere through a 244-m (800-ft) stack. Both Units 5 and 6 exhaust into the same stack.

The Unit 6 configuration required monitoring points to be located at each scrubber module inlet and at the combined outlet breaching prior to entering the stack. Sulfur dioxide and diluent (O_2) measurements were required at the inlet locations and SO_2, NO_x and diluent at the outlet location. It was considered mandatory that both inlets be monitored because the boiler, precipitator modules, and booster fans prior to the scrubber system could result in significant flue gas nonhomogeneity.

The multilocation extractive system shown schematically in Figure 2 was specified by GCA and designed and constructed by KVB Inc. The system consisted of the two sets of gas sensors and associated conditioning hardware and data acquisition equipment as listed in Table 1. One set of instruments was dedicated to the inlet measurements of SO_2 and O_2 on a time-shared cycling basis, and the second set was used on a continuous basis for measuring

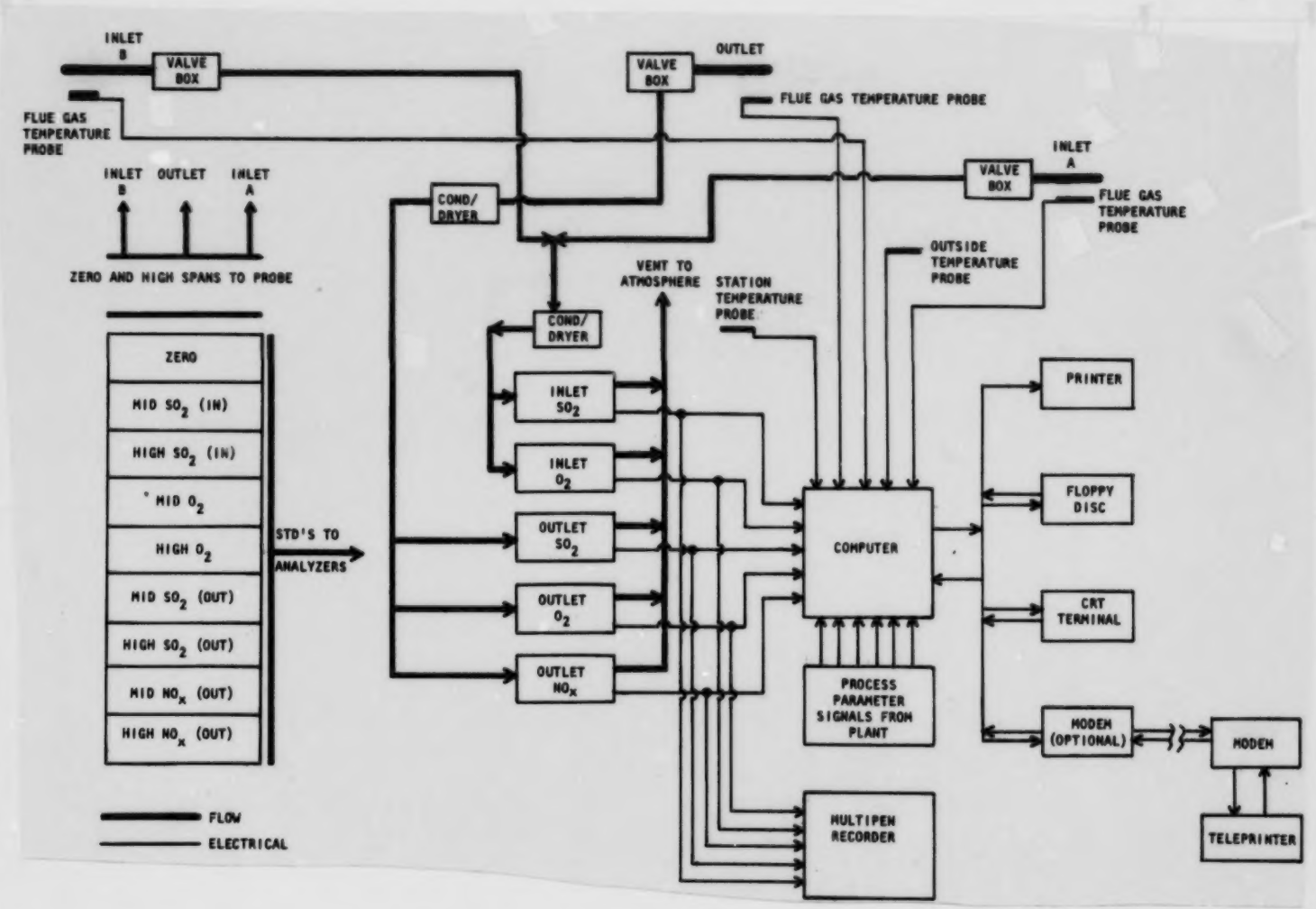


Figure 2. Conesville monitoring system block diagram.

outlet concentrations of SO_2, O_2, and NO_x. Samples were conditioned by filtering out particulates at the sample extraction location. Particulate matter was first removed using an in-stack filter. Material not removed by the in-stack filter was removed by a high-surface area glass fiber filter. Moisture was removed using a dual-pass condenser which was located in the instrumentation shelter. The KVB system was designed to operate automatically. This included multipoint calibrations, zero/span checks, automatic data acquisition, and onsite data reporting.

TABLE 1. MAJOR KVB SYSTEM COMPONENTS

INLET MEASUREMENTS

- Sulfur Dioxide--DuPont Model 400; 0-5000 ppm
  Oxygen--Thermox WDG III; 0-25 percent

OUTLET MEASUREMENTS

- Sulfur Dioxide--DuPont Model 400; 0-1000 ppm (Normal Range)
  1000-5000 ppm (Auto Range)

  Oxides of Nitrogen--Thermo Electron Model 10A; 0-1000 ppm
  Oxygen--Thermox WDG III; 0-25 percent

COMPUTER SYSTEM

- Cromemco
- Dual 8 inch floppy disc drive
- CRT Terminal
- Report Format Printer

EXTRACTION SYSTEM

- Particulate Removal--Filtration
- Moisture Removal-Dual Pass Condensation

In the following subsections, the results of the program are summarized. The presentation is subdivided into three categories which deal with system performance, system availability and economic issues. Concluding the Executive Summary is a Conclusions Section based on the program results.

TABLE 2. SO_2 STRATIFICATION TEST SUMMARY

	Inlet A	Full load A & B modules				Half load A module		Half load B module	
	May 1981	6/1/81	7/17/81	12/11/81	6/10/82	7/18/81	12/12/81	7/19/81	12/12/81
Average duct concentration	3352	1091	853	593	24	1346	843	1615	1182
Std. dev.	212	556	473	339	83	1185	639	247	69
Min.	3214	331	230	191	138	237	243	800	1077
Max.	4321	1853	1640	1150	423	3466	2240	1967	1318
Monitor extraction point concentration	3294	1058	741	374	240	358	358	1849	1232
Ratio of monitor extraction point: average duct concentration	0.983	0.970	0.869	0.631	1.000	0.266	0.425	1.14	1.06

Note: All concentrations are in units of ppm (v/v) and temporally corrected.

amount of stratification as shown by ratios of 1.14 and 1.06. Tests were only conducted at half and full load conditions due to the unit operational profile. Unit 6 is not normally operated otherwise.

Performance Specifications Tests

The monitoring system performance was assessed using the Performance Specifications Tests as outlined in the October 10, 1979 Federal Register. These tests provide a basis for determining adherence to minimum compliance monitoring system performance levels. Tests were conducted which quantify both short term and long term drift, calibration error (precision), response time and system accuracy relative to the reference methods.

These tests were conducted during the latter part of May and the first week of June 1981. An abbreviated version of these tests was conducted during the last month of the program (August 1982). During this last test session, the relative accuracy and calibration error tests were repeated.

A test results summary is shown in Table 3. The entire monitor system conformed to all performance criteria with the exception of the outlet SO_2 monitor which exceeded the 24-hour drfit and mid-scale calibration error criteria. As a result of the drift exceedance, the monitor was equipped with an automatic zero function which rezeroed the analyzer every 15 minutes. The mid-scale calibration error result exceeded the specification during the first tests and was within specified limits during the final test series.

The primary reason for the initial exceedances is most likely related to the mode in which the amplifier signals was processed. DuPont selects the highest full scale range by utilization of the proper bandpass filter and appropriate cell path length. For full scale ranges on the order of 5000 ppm, a bandpass filter which selects a less sensitive SO_2 absorption band is employed. The opposite is true for more sensitive operations.

Since the outlet DuPont analyzer was equipped with a one to five autorange function, the full scale operating range, in all actuality, was 5000 ppm and not the normal 1000 ppm range. The analyzer normally operated in the 1000 ppm range until the flue gas concentration exceeded this value. Upon exceeding 1000 ppm, a resistance bridge was utilized to expand the range by division of the amplifier output. When using this range change mode, the noise level is also expanded by the same amount. For example, if the autorange noise level (5000 ppm range) is approximately equal to 1 percent of full scale, the noise level when operating in the 1000 ppm range will be approximately equal to 5 percent of full scale. A review of the outlet 24-hour drift results versus those obtained from the inlet DuPont (0-5000 ppm) range supports this conclusion. The inlet zero drift was less than 1 percent and the outlet zero drift for the 1000 ppm scale is roughly 4 to 5 times greater.

The mid-scale calibration error exceedance could also be a result of the autorange function. In reality, the mid-scale calibration gas for the 1000 ppm range constitutes only 10 percent of the 5000 ppm range. Because of

TABLE 3. PERFORMANCE SPECIFICATION TEST SUMMARY CONESVILLE CEMS

	Inlet A		Inlet B		Outlet			
	DuPont SO_2	Thermox O_2	DuPont SO_2	Thermox O_2	DuPont SO_2	Thermox O_2	TECO NO_x	Hi Range SO_2
2 Hour Drift								
Zero	0.1% FS	0.01% O_2	0.4% FS	0.10% O_2	1.0% FS	0.2% O_2	0.7% FS	0.3% FS
Cal	0.7% FS	0.05% O_2	0.9% FS	0.2% O_2	2.00% FS	0.2% O_2	0.9% FS	0.6% FS
24 Hour Drift								
Zero	0.3% FS	0.1% O_2	0.8% FS	0.2% O_2	3.2% FS[a]	0.2% O_2	0.8% FS	0.8% FS
Cal	2.5% FS	0.1% O_2	1.7% FS	0.6% O_2	6.4% FS[a]	0.2% O_2	1.6% FS	1.7% FS
Calibration Error								
June 1981								
Mid	1.4%	1.7%	0.9%	1.5%	6.7%[a]	0.8%	2.3%	NA
High	0.5%	1.1%	0.6%	0.9%	1.6%	2.5%	1.2%	NA
August 1982								
Mid	4.7%	3.8%	4.0%	2.2%	4.6%	1.0%	3.8%	NA
High	3.1%	3.7%	4.7%	2.6%	2.2%	2.4%	1.5%	NA

	Inlet		Outlet		
	DuPont SO_2	Thermox O_2	DuPont SO_2	Thermox O_2	TECO NO_x
Relative Accuracy					
June 1981					
Analyzers	4.3%	0.46% O_2	10.9%	0.3% O_2	12.8%
System	6.5%		15.6%		15.2%
August 1982					
Analyzers	9.8%	0.53% O_2	3.9%	0.43% O_2	12.7%
System	9.8%		4.8%		14.8%

[a]Denotes exceeded PST criteria; instrument modified to rectify drift problem.

the low relative value (10 percent of full scale), the precision is altered by the noise level. In addition, there is a slight nonlinearity associated with this portion of the operating range.

The relative accuracy tests conducted at the beginning and the conclusion of the demonstration phase indicate performance consistent with regulatory requirements. During the initial tests, the inlet and outlet SO_2 relative accuracies on a system basis (emission rate) were 6.5 percent and 15.6 percent respectively. Results for the concluding test were comparable with inlet and outlet relative accuracies of 9.8 percent and 4.8 percent respectively. Relative accuracies for the NO_x monitoring system on an emission rate basis were not appreciably different when comparing the two tests. The initial relative accuracy was 15.2 percent and the concluding result was 14.8 percent.

Accuracy and Precision

Over the past 10 years, the Environmental Protection Agency has been involved in the development and evaluation of methods to monitor and control sulfur dioxide emissions from utility boilers. Throughout this period, significant improvements have been made in both areas. As an extension to the monitoring methodologies currently in use, the Quality Assurance Division of EPA is formulating and evaluating quality assurance measures which can be applied to power plant monitoring situations. These procedures include protocols for demonstrating the accuracy of the data relative to a reference method as well as a simple daily routine to determine the precisions of the measurement equipment on a monthly basis. The quality assurance procedures are currently in the proposal stage and may be soon promulgated as Appendix F of 40 CFR 60.

In order to demonstrate the utility of these methods, GCA conducted the accuracy and precision estimating methods. Various draft versions of Appendix F were prepared during the 1980-1982 time frame. The precision and accuracy checks were conducted according to the November 19, 1981 version.

Accuracy--

Proposed Appendix F provides two options for assessing system accuracy. One option involves the use of standard gases in which the standard gas is analyzed and processed as a flue gas sample. The second option involves side by side comparisons of CEMS outputs using the applicable reference methods. For the purposes of this program, the reference method option was chosen.

The results of the relative accuracy audits are shown in Table 4. Also included in this table are the results of the initial and final relative accuracy tests for comparative purposes. Each relative accuracy audit consisted of at least 6 valid test replicates whereas the initial and final relative accuracy tests consisted of 9 replicates.

TABLE 4. SUMMARY OF RELATIVE ACCURACY AUDITS

Date	Inlet			Outlet			Outlet	
	SO_2	O_2	System	SO_2	O_2	System	NO_x	System
June 1981	4.3	0.46	6.5	10.9	0.28	15.6	12.8	15.2
July 1981	11.6	0.55	15.0	16.0	0.40	16.9	6.7	9.7
June 1982	6.5	0.68	7.8	13.3	0.19	12.8	17.2	17.7
July 1982	7.4	1.53	9.4	12.9	0.24	14.2	23.7[b]	23.2[b]
August 1982	9.8	0.53	9.8	3.9	0.43	4.8	12.7	14.8

[a] SO_2, NO_x and system are in terms of % relative accuracy; O_2 is in terms of % O_2 concentration.

[b] Exceeded the allowable criterion of $\leq$20%.

The inlet and outlet SO_2/O_2 monitoring system exhibited relative accuracies in the range of 4.8 percent to 16.9 percent on an emission rate basis. When reviewing these results, it is useful to note that the monitoring system and reference methods each contributed an imprecision and bias component to the relative accuracy result.

The NO_x results were in the range of 9.7 percent to 23.2 percent on an emission rate basis. During the July 1982 audit, the relative accuracy exceeded the allowable 20.0 percent criterion. A review of this result indicates a comparable bias ( ) to other test periods; however, the confidence interval (precision component) was much larger than before.

Precision--

Data obtained from the daily calibration checks were utilized to estimate the upper and lower probability precision limits for each analyzer. These estimates were determined using the protocol delineated in the proposed Draft Appendix F Quality Assurance procedures dated 11/19/81.

Initially, a calibration equation was determined by inputting multiple span gases directly to the analyzers (bypassing all conditioning equipment) and recording the voltage responses. The resulting coordinate pairs were used to construct linear calibration equations. These equations were reconstructed every 5 to 7 days.

On a daily basis, the zero and high span gases were input through the entire system (including all extraction equipment) and analyzed as a sample gas. The resulting voltages were substituted into the appropriate calibration equation to determine the corresponding concentration in units of ppm SO_2, NO_x or percent O_2.

Using the basic data inputs described in the previous paragraph, the upper and lower probability estimates for the zero and high span levels were calculated by determining the relative differences between the measured span (zero) gas concentration and the accepted concentration. Subsequently the upper and lower precision limits were calculated by adding and subtracting 1.96 times the standard deviation of the differences from the mean difference.

The precision results for each monitoring location are shown in Table 5. In most cases, the monthly estimates were calculated using at least 25 days of data. June and July of 1981 were periods of data collection where the poorest system availability and data capture were encountered. The system was brought online and certified near the end of May (1981). During the ensuing 2 month period, the system underwent considerable debugging and it was envisioned the precision intervals should indicate poorer system performance.

Data for the inlet monitoring system as a whole (all analyzers) exhibited the poorest performance during the period January-September 1982. For the most part, span interval ranges were on the order of 20-30 percent while the zero interval ranges were on the order of 5 percent. It is not completely understood why these results are much higher than the outlet except to note that the inlet zero span system was consistently trouble prone. During this cycle, valve sticking often caused erroneous zero and span data generation. It was noticed throughout the course of the program that the indicated drift was not normally real and was a result of valving problems. Since the zero/span data were only used as a control check and not for scaling purposes, the monitoring data were considered valid the majority of the time, even though the zero span data indicated otherwise.

Results for the outlet monitors exhibited the best performance during the period May-September 1982 in which all interval ranges for both zero and span were less than 10 percent. Interval ranges for the initial period of June-September 1981 were slightly larger than the last 4 month period occurring in 1982. Much of the lower performance occurred during the June-July time period in which considerable system problems occurred followed by significant troubleshooting activities.

Results for the outlet SO_2 analyzer show marginal improvement for the span level from the first 4 months of operation to the last 8 month period and a significant improvement at the zero level. An automatic zero control was installed during September 1981 to reduce zero drift. The zero control automatically readjusted the zero value every 15 minutes during the conditioning system condenser blowdown cycle. This addition was made in order to meet the 24-hour calibration drift criteria.

TABLE 5. PRECISION ESTIMATE RESULTS SUMMARY CONESVILLE CEMS

Inlet CEMS probability limits

		A O_2				B O_2				A SO_2				B SO_2			
		STAR		EXAM		STAR		EXAM		STAR		EXAM		STAR		EXAM	
Year	Month	UPL	LPL	UPL	LPL	UPL	LPL	UPL	LPL	UPL	LPL	UPL	LPL	UPL	LPL	UPL	LPL
1981	June	2.4	-5.3	0.8	-0.7	3.3	-5.3	3.8	-1.1	6.2	-6.7	2.6	-1.4	10.8	-3.4	4.2	-1.4
	July	1.3	-4.1	1.4	-1.1	13.7	-14.4	2.2	-1.8	2.7	1.0	6.0	3.3	3.5	-9.4	6.8	-3.5
	August	1.3	-11.3	0.8	-0.7	3.6	-11.3	3.4	-2.3	3.6	-5.6	5.3	-1.6	4.3	-5.4	6.9	-2.8
	September	-7.5	-11.7	0.2	-0.3	-2.1	-13.0	5.4	-2.3	4.9	-1.9	13.3	-3.5	16.5	-1.9	13.8	-2.7
1982	January	3.4	-26.7	0.2	-0.1	5.1	-22.7	0.3	-0.3	17.1	-25.5	0.1	-0.9	18.7	-15.6	-0.1	-1.0
	February	-2.9	-6.3	0.2	-0.3	16.6	-29.4	4.7	-4.7	1.7	-6.3	2.2	0.9	13.4	-24.8	7.6	-3.1
	March	-0.6	-6.0	0.2	-0.2	16.1	-26.1	2.2	-2.0	6.9	-18.5	0.8	-1.4	19.4	-29.0	9.4	-1.2
	April	21.1	-25.0	18.7	-12.0	20.3	-28.5	2.9	-1.1	-15.4	-13.8	13.9	-12.1	29.8	-44.9	2.9	-1.6
	May	1.1	-11.3	1.4	0.1	4.3	-6.7	3.0	-0.4	25.5	7.7	13.8	-4.3	13.7	12.7	10.8	-2.7
	June	-0.1	-13.3	1.2	-1.0	-0.4	-12.4	1.9	-1.9	13.6	-1.3	4.2	-0.9	14.3	-3.9	4.3	-1.0
	July	-3.4	-10.0	0.8	-0.4	-3.6	-9.9	1.0	-0.3	10.1	-8.8	3.0	-1.6	10.7	-10.4	3.7	-2.1
	August	3.8	-20.0	0.3	-0.2	3.3	-20.7	1.7	-0.9	14.0	-6.2	4.6	-1.4	13.8	-5.4	4.6	-1.1

Outlet CEMS probability limits

		O_2				SO_2				NO_x			
		STAR		EXAM		STAR		EXAM		STAR		EXAM	
Year	Month	UPL	LPL	UPL	LPL	UPL	LPL	UPL	LPL	UPL	LPL	UPL	LPL
1981	June	2.1	-3.8	1.0	-0.6	9.5	-6.4	24.9	-3.0	5.1	-1.6	2.2	-0.9
	July	5.6	-6.5	2.0	-1.7	-13.2	-14.0	4.6	-0.2	10.3	-6.1	1.3	-0.9
	August	7.8	-4.7	1.3	-0.5	13.4	-7.1	11.6	-6.2	4.3	-1.1	1.7	-1.3
	September	0.1	-2.7	0.1	-0.1	6.1	-2.5	3.6	-0.2	4.9	-17.6	1.2	-0.7
1982	January	-3.2	-4.2	0.1	-0.1	4.5	-11.7	3.6	-0.9	19.8	972.6	1.7	-1.5
	February	33.8	-64.7	17.6	-13.7	11.4	-15.5	3.4	-1.5	6.5	65.1	1.8	-1.0
	March	-2.6	-4.1	0.2	-0.3	28.7	-44.7	4.0	-2.3	6.5	-8.9	1.3	-1.0
	April	0.9	-4.4	1.2	-0.6	13.6	-12.2	13.5	-2.1	7.9	-18.9	1.3	-1.3
	May	0.6	0.0	0.0	0.0	4.6	3.7	4.1	2.6	-2.7	-5.2	0.7	-0.9
	June	2.4	-0.9	0.2	-0.2	6.4	-4.3	4.5	-2.4	0.2	-8.7	0.8	-1.5
	July	6.6	-4.4	0.3	-0.2	0.3	-10.7	3.1	-1.3	-7.1	-14.9	1.9	-1.8
	August	4.9	-7.5	0.3	-0.3	7.2	-10.0	2.3	-0.6	19.9	-23.5	1.6	-2.0

UPL = Upper Probability Limit

LPL = Lower Probability Limit

CEMS AVAILABILITY

Two definitions of availability are presented for the purposes of this discussion. Total availabilities refer to a simple proportion of CEMS uptime to boiler uptime on an hourly basis. This proportion is also modified to conform to Subpart Da requirements. The requirements set forth in Subpart Da include definitions of valid periods of data that are required for reporting purposes. A valid data hour must consist of at least two quarters of data; a valid daily average must contain at least 18 hours of data for a 24-hour, midnight to midnight, boiler operating day. A valid 30-day rolling average must contain at least 22 valid days of data.

Figure 3 shows hourly valid monitoring data availability based on the number of boiler operating hours within each calendar month. The primary Subpart Da reporting parameters are outlet sulfur dioxide and oxides of nitrogen emission rates (ng/J) and the control unit sulfur dioxide removal efficiency. Emission rates are calculated using the data generated by the pollutant and diluent monitor combination. Similarly, the sulfur dioxide removal efficiency is calculated using concurrent data generated by the inlet SO_2/O_2 and outlet SO_2/O_2 monitor pairs.

The hourly availability rates shown in Figure 3 range from 38 to 90 percent for the outlet SO_2 emission rate, 18 to 90 percent for the NO_x emission rate, and 35 to 88 percent for the removal efficiency parameter. Overall, the outlet SO_2 emission rate availability averaged 78 percent, the NO_x emission rate averaged 65 percent, and the removal efficiency parameter averaged 75 percent.

Table 6 summarizes the overall availability, indicates the adherence to the Subpart Da data capture requirement on a daily basis and shows the data availability for reporting the 30 day rolling averaged data. In total, there were 277 "boiler operating days (as defined in Subpart Da)" during the demonstration phase. For these boiler operating days, the daily data capture rate for outlet sulfur dioxide emission rate was met 72 percent of the time while the removal efficiency availability requirement was slightly less at 69 percent. The daily NO_x reporting requirement was met 59 percent of the time. Approximately half of the NO_x data unavailability was due to NO_x vacuum pump failure.

Subpart Da 30 day rolling average availabialities were 67 and 59 percent for the SO_2 outlet emissions and removal efficiency, respectively. The availability for the NO_x reporting requirement was 62 percent. For those rolling averages which do not fulfill the minimum data capture requirements, the upper and lower confidence intervals for each parameter are calculated. The upper limit is used for reporting outlet emission rates and the ratio of the upper outlet emission limit and the lower inlet interval limit are used to report the efficiency parameter. Based on the total Subpart Da reporting structure, the CEMS provided the data for meeting the reporting requirements essentially 100 percent of the time.

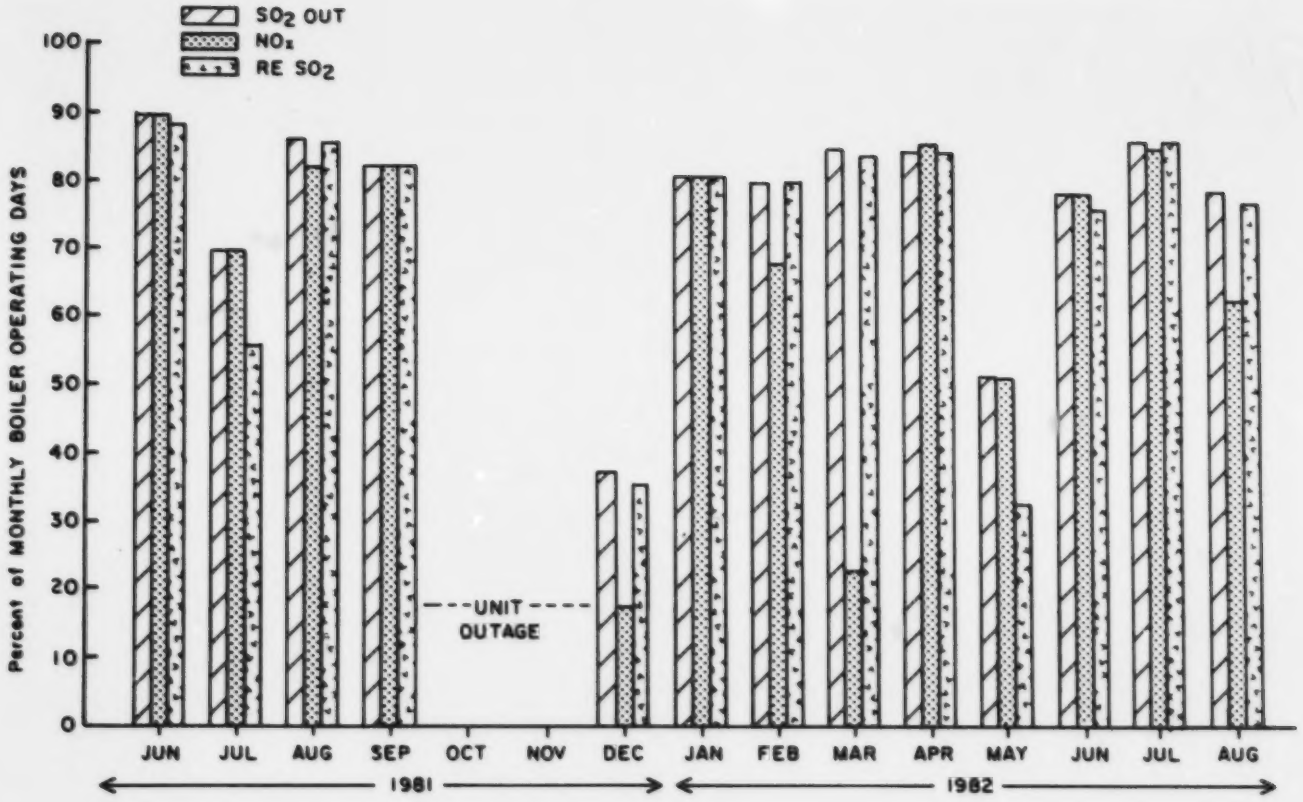


Figure 3. Monitoring data availability by calendar month for outlet SO_2 and NO_x emission rates and sulfur dioxide removal efficiency (percentage of CEMS Uptime relative to total boiler uptime hours).

TABLE 6. AVAILABILITY SUMMARY FOR REQUIRED SUBPART Da REPORTING REQUIREMENTS

Parameter units	Outlet SO_2 Emissions	Outlet NO_x Emissions	SO_2 Removal Efficiency
Total availability % total Unit 6 uptime	78	65	75
24 hour availability[a] % valid 18-24 hour days	72	59	69
Subpart Da availability % of valid 30 day rolling averages	67	62	59

[a]Total number of boiler operating days equal 277.

ASSESSMENT OF ECONOMIC REQUIREMENTS

The economic impact of continuous monitoring regulations is an area of concern for the source as well as the lawmaker. Although an assessment of economic variables was not one of the primary objectives of this program, some interesting cost information is available. The cost data presented are based solely on the actual costs associated with the Conesville program. The applicability of these costs to other utilities installations is anticipated to be useful if site-specific variables are taken into consideration.

The utility operator experiences two major expenditures in fulfilling the Subpart Da reporting requirements. Initially, major capital expenditures are made in purchasing, installing and certifying a monitoring system. Subsequently, ongoing costs are incurred from routine operation and data reporting.

Figure 4 presents a pie-chart breakdown of the "premonitoring" costs associated with the Conesville CEMS. The purchase price (including delivery) for the system totalled $181,000 delivered to the test site. Prior to installation, $31,030 were spent to build a temperature controlled monitor room, and to route electrical wiring and sample lines. These preparations were conducted by a local area contractor. Final installation, startup and checkout were conducted by the vendor and accounts for costs of slightly less than $35,000. Following startup and conditioning, the certification tests were conducted by GCA at a cost of $21,000.

Figure 4. Phase II relative cost summary.

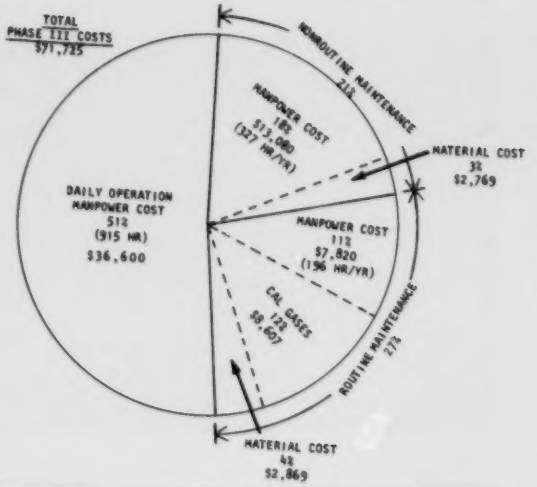


Figure 5. Phase III relative CEMS operational costs.

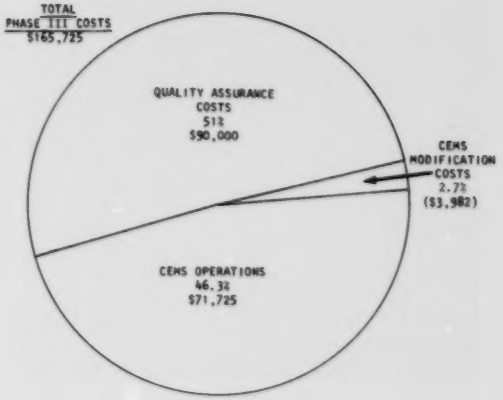


Figure 6. Phase III overall relative costs.

Figure 5 shows a pie chart breakdown of the Phase III operational costs experienced at Conesville and Table 7 provides a further breakdown of the labor requirements. The Phase III labor hours totalled 915 hours (17 hrs/week) for daily operations, 327 hours (27 hrs/month) for nonroutine maintenance and 196 hours (16 hrs/month) for preventive maintenance. Nonroutine materials costs totalled $2,769 and routine expendible materials costs totalled $2,869. One should note that the nonroutine material costs are biased low due to the fact that many of the replacement parts were supplied under warranty free of charge.

Figure 6 shows a comparison of the CEMS operations costs described by Figure 5 in reference to the total quality assurance activities conducted during Phase III. The quality assurance costs totalled $90,000 and covered an initial and final performance specifications test series, three abbreviated relative accuracy audits, four stratification test series and the calculation of monthly precision estimates. Presently, the utility operator is required to conduct the initial performance specifications test series and a location representativeness (stratification) test. Future regulations may include the reporting of precision estimates and the conduct of a yearly relative accuracy audit and/or a cylinder gas audit.

CONCLUSIONS

While the results of the program do not fully answer all questions concerning continuous monitoring, several conclusions and/or judgements can be made. Statements made concerning this program should be prefaced by several qualifiers. First and foremost is that the experience and results may be specific to the Conesville monitoring situation. Second there were several economic constraints which precluded implementation of system modifications which would have most likely improved system uptime.

Conclusions are broken down into the following primary areas. These include:

- Design deficiencies
- Software deficiencies
- Availability
- Projected utility costs

Design Deficiencies

There were several design deficiencies noted which severely hampered availability and the subsequent fulfillment of reporting requirements. The primary problems were not hardware related but were more "action and reaction" related; specifically, the area of system reaction to alarm conditions. KVB configured this system to be totally automated with all operation and control functions "slaved" to the computer. This included every system function such as valve cycling sequence and even pumping system power. As a result of this configuration, normal data acquisition ceased whenever computer operations

TABLE 7. CEMS OPERATION MANHOUR REQUIREMENT SUMMARY

	CEMS Maintenance Summary									
	Conditioning System		Analyzers		Computer		Total		Daily Operations	Total Manhour Requirements
	NR	R	NR	R	NR	R	NR	R		
Total Hours	242	62	60	118	25	16	327	196	915	1437
% Total	17%	4%	4%	8%	2%	1%	23%	14%	64%	---
Weekly Average Hours	4.5	1	1	2.2	0.5	0.3	6	4	17	27

NR = Nonroutine Maintenance
R = Routine Maintenance

terminated. Provisions should be made for the system to operate in a manual mode during computer outage. The system was equipped with a backup strip chart recorder; however, this backup recorder served no useful purpose since all monitor functions were terminated when a computer crash occurred. A timer subsystem could be included which takes over control functions such as condenser draining, inlet valve cycling, etc., when a computer outage occurs.

Other problems were related to the conditioning and switching systems. The weak link responsible for the majority of hardware related downtime was the valve switching system. This system primarily used solenoid type valves which are prone to sticking. In addition, these valves cannot be monitored by a computer to ascertain actual valve position. These valves could be replaced with multiport ball types. Ball valves do not stick or fail at the rate of the solenoid type. In addition, these valve actuators provide a position signal which indicates that a specified valve command has been completed.

The NO_x converter and vacuum system were responsible for a major portion of NO_x downtime. When exposed to high-sulfur and chloride laden flue gases, the stainless steel converters show a high corrosion rate. Bypassing the converter would eliminate this problem. The NO_x vacuum pump was failure prone for unknown reasons. It appears that the best approach for maintaining uptime is to keep a spare pump on hand.

The computer disc system was very failure prone. Repeated read/write errors resulted in significant data loss. Much of the problem can be attributed to dust. Aside from the read/write problems, the durability of the floppy disk system for field applications is questioned. During the 16 month demonstration phase, the disc system was replaced once and underwent significant component replacement on another occassion. For future applications, a sealed Winchester or electronic type disc storage device is recommended.

Software Deficiencies

There were two primary deficient software areas. The first area deals with "alarm actions and reactions" and has been described in the previous subsection. The second area deals with the system reporting functions. The first problem was associated with the manner in which the data were stored on disc. Since the data were scaled and then stored as a reduced value, these data could not be corrected if an incorrect calibration equation were being used for scaling. If the voltages were stored instead of the reduced values, the calibration factors could be corrected and the data reduction conducted during report output.

The KVB software had no provisions for editing. Report generating routines used all data stored on disc; even data generated during unit outages, instrument malfunctions, etc. Due to the lack of an editing routine, 30 day rolling averages were calculated using all data stored on disc. As a result, the report routine was of little use in preparing automated quarterly reports.

Availability

The overall availability for future systems of this sort can be improved significantly by implementing several generic design changes. Based on the results of this study, future systems should be configured in two basic subsystems. These include the conditioning/monitoring subsystem and the data storage/reduction system. In addition, these two systems should be separable; that is if the data system is removed, the monitoring subsystem continues to collect and store data on a secondary system such as a strip chart recorder. Data availability should be significantly higher using this approach since the monitoring process is not terminated upon the ceasation of computer control.

Other considerations should be given to the servicing of alarm conditions. Often times, the computer system terminates system operation for what may be a very minor problem. The power plant environment is well geared toward the use of enunciator panels to report alarm conditions. After acknowledging these types of alarms, the appropriate action is taken.

Automatic routines such as calibrations should be scheduled during time periods when more personnal are on duty. Considerable downtime was encountered during the Conesville Program as a result of an automatic function occurring at midnight and going undiscovered until morning due to the unavailability of personnel to correct the problem.

Projected Utility Costs

The operational experience gained during the program can be used to project the costs to the utility industry. Yearly operations comprise the largest cost element associated with monitoring. It is estimated that approximately 900 man-hours per year will be expended to operate the system, verify the data being stored and acquire the proper process and monitor documentation for preparing the quarterly Subpart Da and Appendix F reports.

Quarterly relative accuracy audits constitute the next major labor requirement. Approximately 140 man-hours per audit will be expended if conducted by inhouse personnel. An outside contractor would charge approximately $10,000 per audit including travel.

Routine maintenance labor constitutes about 8 percent of the yearly level of effort or 210 man-hours. This level may be elevated slightly as the maintenance schedules are refined. It is anticipated that the nonroutine maintenance level would be reduced with a slight increase in preventive maintenance.

Nonroutine maintenance has been estimated at slightly over 310 man-hours per year. This level appears to be higher than expected and should decrease with time as the preventive maintenance program is refined.

Quarterly Subpart Da and Appendix F (Draft) reports are projected at a combined yearly total of 220 man-hours. This level is based on the use of an automated data reduction system.

Calibration gas cost is the single largest quarterly expendable material expense and most predictable utilizing automatic analyzer calibration systems in which the gas is injected at the probe locations. The estimated yearly cost (based on the Conesville system is $13,940 using Protocol 1 certified span gases. Other types of systems which use gas diluters for blending the various span gas concentrations will reduce by 30 percent the amount of gas required to calibrate the system.

The spare parts inventory cost represents a significant additional cost to the original purchase cost of a CEMS. Useage rate and quarterly replacement cost is difficult to predict. A good warranty maintenance agreement with the CEMS vendor can drastically reduce this cost for the first years of CEMS operation. An adequate spare parts inventory for the Conesville system would approach $11,600 or 6.4 percent of the system cost.

SECTION 3

PROGRAM APPROACH

The test program was planned with four distinct phases in mind. Phase I involved the selection of a test site, the determination of system requirements/capabilities and, finally, the issuance of a project quality assurance plan. Based on the phase I preparatory work, the defined system was procurred, installed and made operational according to the regulatory specifications during phase II. Subsequently, during phase III, the system was operated and evaluated during a 16 month period. The data and experiences obtained during the first three program phases were evaluated in phase IV.

PHASE I--PROJECT PLANNING TEST SITE SELECTION AND SYSTEM SPECIFICATION

The phase I activities initially consisted of the preparation of a work plan, selection of a test site, a system design and specification phase and development of a quality assurance plan which was tailored to the planned program. Originally, the entire program approach was delineated in the form of a work plan. This work plan was modified several times because of changes in scope and approach.

In the following subsections, the test site selection and system design specification segments are discussed. No further discussions are provided for the work plan[1] and quality assurance plan[2] since both are parallel, self-standing documents describing approaches for the entire test program.

Test Site Selection

Following the completion of the project work plan, a test site selection process ensued. Since the intent of the program was to simulate subpart Da monitoring requirements, it was important to select a unit which would provide circumstances similar to subpart Da monitoring situations. At the time the program was initiated, there were no operational units subject to subpart Da.

As a result, selection criteria were cooperatively prepared by GCA and the EPA project officer. These criteria were as follows:

- Coal-fired steam generator, 100 MWE minimum, less than 10 years old.
- Coal sulfur content between 2 to 5 percent and medium to high ash content (e.g., 10 to 30 percent).

- Flue gas desulfurization system designed for a minimum of 80 percent SO_2 removal on 100 percent of the flue gas.

- Flue gas desulfurization system which employs multiple scrubber modules in parallel.

Based on these criteria, a list of possible sources was assembled and request letters sent to the respective source operators. Twelve facilities were contacted and three responded. The three responses were as follows:

- Columbus and Southern Ohio Electric Company (CSOE), Conesville Unit Nos. 5 or 6.

- Central Illinois Public Service Company (CIPS), Newton Unit No. 1.

- Springfield City Utilities (CU), Southwest Unit No. 1.

In the following subsections, each facility is described. Concluding the subsection is a discussion outlining the reasons for the final selection.

Conesville--

The Conesville Power Station is operated by the Columbus and Southern Ohio Electric Company (CSOE) and is located in Conesville, Ohio approximately 85 miles east of Columbus, Ohio. Units 5 and 6, which are identical were the two available choices for conducting the monitoring program. Each units is rated at a gross generating capacity of 411 MWE and the pollutant control system is designed to handle 100 percent of the boiler exhaust gases. The units were designed to burn coal containing a maximum of 4.7 percent sulfur and 15 to 17 percent ash.

Conesville Units 5 and 6 each use a dual module precipitator built by Research Cottrell for particulate removal and a wet thiosorbic limestone scrubber system designed by UOP Air Correction Division for reducing sulfur dioxide emissions.

The general configuration of the two units is shown in Figure 7. In short, the gas exiting the boiler passes through two, parallel preheaters and into a dual module electrostatic precipitator where particulates are removed. The gas exiting the two parallel precipitator modules pass into two ID fans which move the gas through the scrubber modules. Gases exiting the scrubber modules and the bypass duct effluent are combined into a common plenum before entering an 800-foot stack. Both unit exhaust gases are emitted through the same stack.

Newton Unit No. 1--

The second site surveyed was Newton Unit 1 which is operated by the Central Illinois Public Service Company (CIPS) and is located on the outskirts of Newton, Illinois. A Combustion Engineering drum-type boiler with a steam generating capacity of 4,158,619 lbs/hr at 2620 psig and 1005°F is used as the steam generation source. The gases exiting the boiler are passed through a dual module electrostatic precipitator and a Buell Envirotech dual alkali

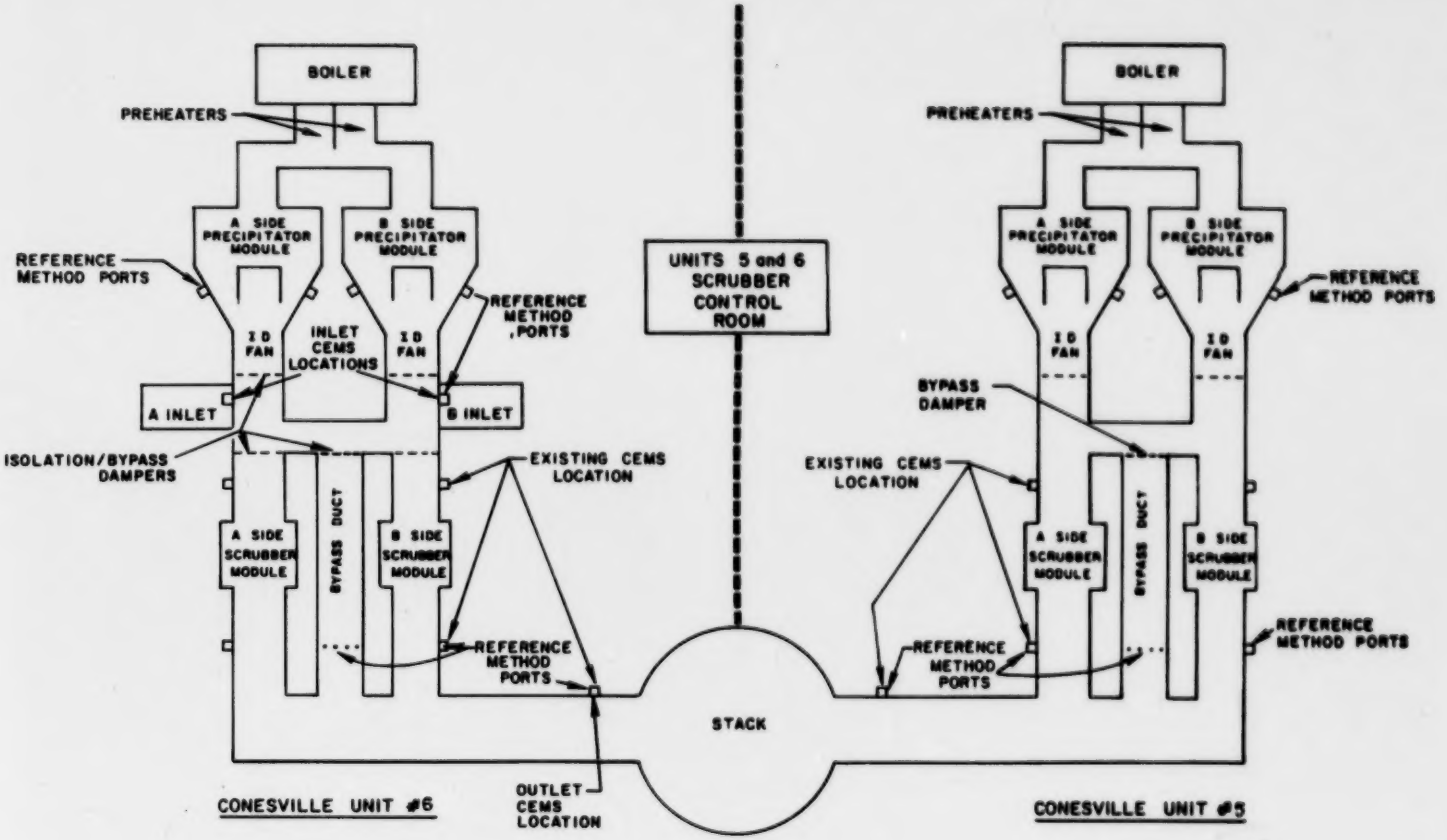


Figure 7. Conesville Units 5 and 6.

scrubber system for subsequent exhaust gas clean up. Design specifications enable the use of high-sulfur, high-chloride, and medium-ash coal. At the time of the survey, CIPS was utilizing coal containing 2.8 percent sulfur, 0.07 percent chloride and 12 to 14 percent ash as the fuel source. The unit is rated at 600 MWE gross power output and the pollutant control system is designed to treat 100 percent of the gas exiting the boiler.

Figure 8 contains a plan view of the scrubber system. The system utilizes four chloride removal spray towers and four tray tower scrubber modules. The system can be subdivided into two separate and totally independent sections. Each half consists of two chloride spray towers, two scrubber modules and a reheat system. One subhalf employs a steam tube-type reheater while the remaining half uses a bypass type reheater.

Gas exiting the precipitator modules pass through two parallel ID fans. The fans have a single outlet and the effluent gases enter into a common plenum. After entering the common plenum the flue gas is introduced into the four pre-cooler chloride scrubber modules by four separate booster fans. Chloride removal and temperature reduction is affected by tangentially introducing a water spray countercurrent to the gas flow. The cooled gas exits the pre-cooler modules and enters the scrubber modules where sulfur dioxide removal occurs. Sulfur removal occurs in each of four tray towers containing free floating arrays of spheres coated with the slurry media. After sulfur removal, the gases exiting the two pairs of tray towers are combined and reheating is accomplished. At this point, the total gas stream from each half, including bypass, is combined and emitted through a temporary 300 foot steel stack. A temporary stack was installed after liner failure was experienced with the main stack.

City Utilities--

The final test facility surveyed is located at the Southwest Power Station on the outskirts of Springfield, Missouri. This unit is operated by the Spingfield City Utilities Company and is rated at a gross capacity of 200 MWE. The unit is designed to burn high-sulfur, medium-ash coal and the pollutant control system is designed to handle 100 percent of the boiler effluent.

Figure 9 is a schematic diagram of the Southwest unit. The boiler effluent passes through a single module electrostatic precipitator and is injected into two parallel wet limestone scrubber modules by a pair of ID fans. The effluent from both scrubber modules is recombined into a 500 foot stack. As shown in Figure 9, the bypass and scrubber effluents enter the stack at different points. No reheater other than bypassed flue gas is utilized on this unit.

Final Test Site Selection--

The EPA project officer and GCA program manager visited each of the three prospective sites to determine which site would best fulfill the project objectives. Sites were evaluated in terms of unit configuration, past records of availability and the degree to which each unit could provide a simulated subpart Da monitoring situation.

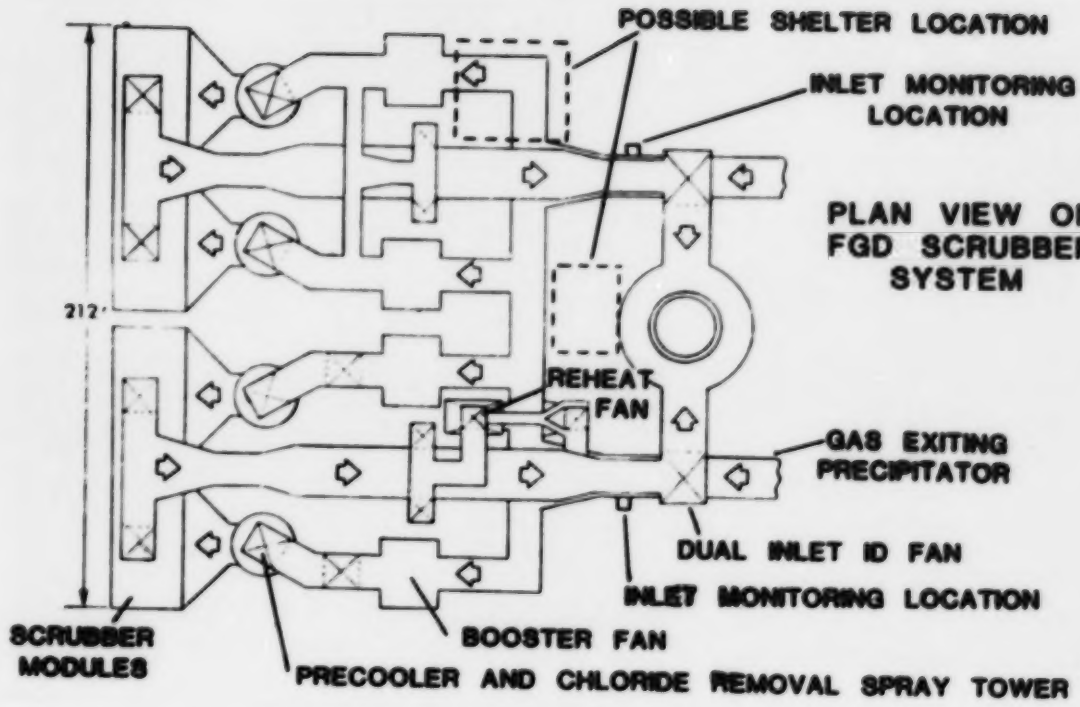


Figure 8. Newton Unit 1--Central Illinois Public Service.

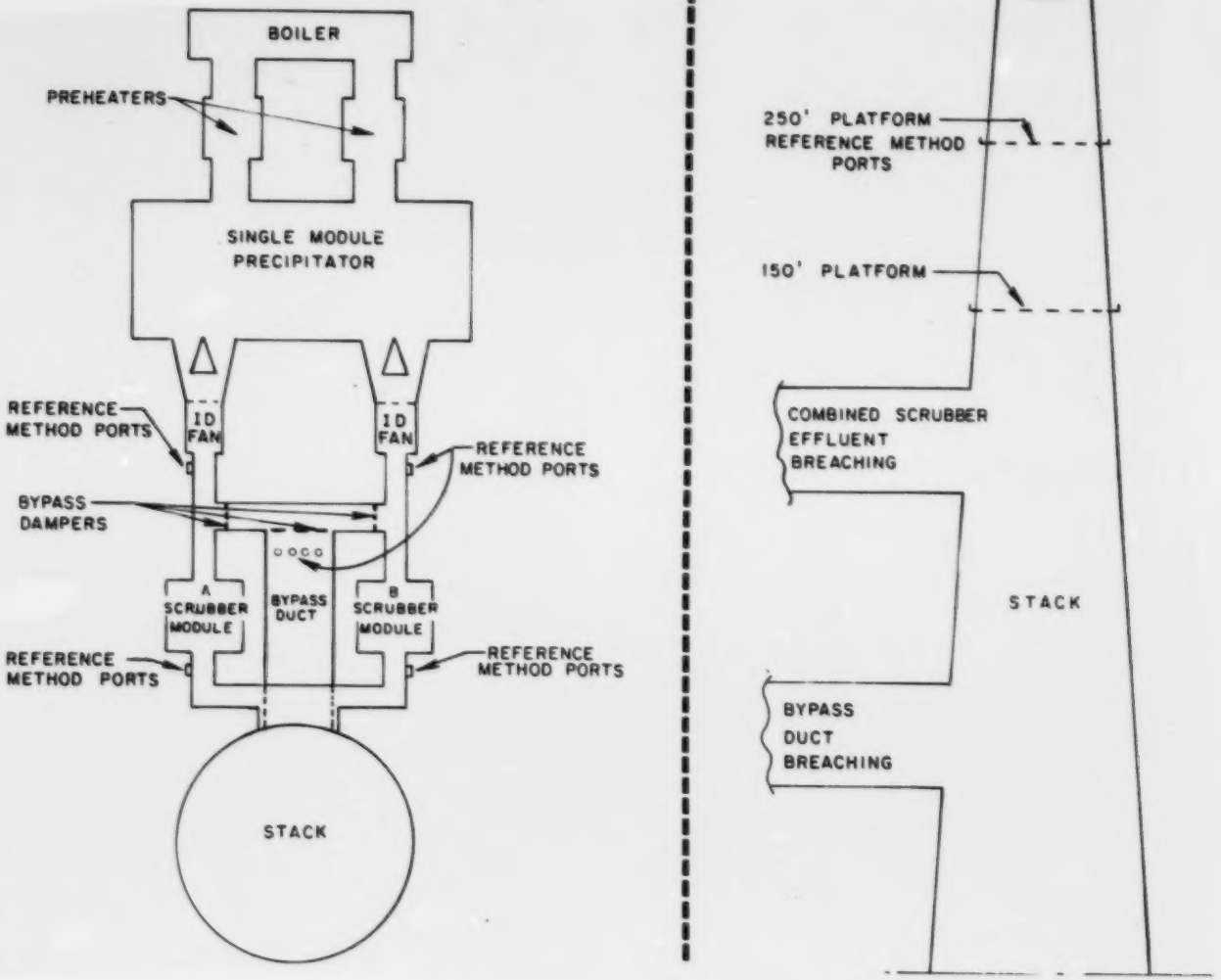


Figure 9. Springfield City Utilities Southwest Plant.

All three facilities conformed to the initial selection criteria and further fulfilled the configuration and subpart Da similarity requirements. The final selection was based on projected unit availability. At the time of the survey, the Newton facility was in the startup phase and was exhibiting availabilities on the order of 40 percent. Similarly, the Southwest Unit exhibited availabilities of less than 50 percent resulting from frequent scrubber pluggage problems. Based on the poor availabilities, the decision was made to conduct the program at the Conesville generating station. Both Units 5 and 6 typically exhibited availabilities of at least 85 percent. Unit 6 was subsequently chosen as the test unit on which the program was conducted. The decision to test Unit 6 was based on the unit outage schedules.

CEMS Design/Specification

Following the completion of the test site selection process, the major efforts were focused on defining the system requirements and design specifications. Initially, the program scope was such that GCA would design, build and operate the system. Prior to the finalization of the system design, Edison Electric Institute (EEI) and Utility Air Regulatory Group (UARG) representatives suggested that the system specification/design phase be conducted to simulate the utility procurement process. In addition, it was the opinion of these two groups that a "real world" evaluation would not be forthcoming if the same organization were allowed to design, build and operate the system.

As a result, two organizations were contracted by EPA to prepare design reports and associated cost quotations. One organization was GCA and the second was KVB Equipment Systems Division of Irvine, California. Both organizations surveyed the selected test site and prepared design quotations according to a set of specifications provided by the EPA project officer.

Both design documents were reviewed by EPA, UARG, and EEI representatives and a selection was made. It was the opinion of the review committee that the KVB system be used in order to provide an independent evaluation of the monitoring equipment.

PHASE II--CEMS PROCUREMENT, INSTALLATION AND CERTIFICATION

Based on the recommendations of the advisory committee, GCA conducted Phase II by procuring the KVB system and making arrangements for installation and startup.

The Phase II approach involved four distinct areas.

- Site Preparations
- CEMS Procurement and Installation
- System Startup
- Certification Tests

Site Preparations

A CEMS room was constructed since no shelter was available at the test facility that provided a suitable environment in which to locate the CEMS hardware and computer system. Site specifications were prepared by CSOE and the costs shared by EPA and CSOE. The site preparations included monitor room fabrication and installation, electrical hook-ups, heat-traced sample line installation, and conduit routing. All mechanical and electrical preparations were performed by local subcontractors.

CEMS Procurement and Installation

Based on the decision of the selection committee, GCA prepared a detailed facility description and system procurement document. KVB subsequently delivered the system approximately 7 months later, 2 months after the original projected delivery date. Delays were experienced in the final system completion and software preparations. Final installation was completed approximately 2 months after the delivery date. An in depth discussion of the system specifications is presented in later sections of this report.

Startup Debugging

Following final installation, a 2 month period was required to make the CEMS fully operational prior to conducting certification tests. During this period system hardware and software design problems and other operational problems were discovered and corrected. Most of the problems involved the operating software and the computer valve sequencing controls required to carry out the various automatic CEMS functions as called for in the system specifications.

Also during this time period, CEMS operators were trained and routine maintenance schedules developed. This 2-month startup was required because the CEMS had not been completely assembled and checked at the manufacturing facility prior to delivery.

Certification Tests

After the system was brought online, GCA initiated the "Performance Specification Test Period. The certification testing was conducted according to proposed "Performance Specifications 2 and 3" as outlined in the October 10, 1979 Federal Register. A summary of the specifications is shown in Table 8.

Initially, the system was operated for a 168-hour period to determine if the CEMS was operationally acceptable for the ensuing performance tests. The system was allowed to operate in its normal data acquisition mode in which the CEMS sampled flue gas unless otherwise undergoing zero/span, calibration or scheduled maintenance.

TABLE 8. PERFORMANCE SPECIFICATION TEST CRITERIA

Test	SO_2/NO_x	O_2
Conditioning period	≥168 hr	≥168 hr
24-hr zero drift	≤2% span	≤0.5% O_2
24-hr cal. drift	≤2.5% span	≤0.5% O_2
24-hr zero drift	≤2% span	≤0.4% O_2
24-hr cal. drift	≤2% span	≤0.4% O_2
Mid-level cal. error	≤5%	≤5%
High-level cal. error	≤5%	≤5%
Response time	≤15 min	≤15 min
Relative accuracy	≤20% of the mean reference value in terms of emission rate	

After successful completion of the 168-hour conditioning period, the various certification tests were conducted. Once the system performance had been demonstrated consistent with these criteria, it was deemed suitable for continuous monitoring purposes and Phase III began.

PHASE III--ONE YEAR FIELD DEMONSTRATION

The field demonstration phase was initiated following the successful completion of the operational test period. The primary purpose of this phase was to operate and maintain a continuous monitoring system in accordance with Subpart Da requirements.

The Phase III approach was based on the requirements delineated in the following draft, proposed or promulgated regulations:

- 40 CFR Part 60, Subpart Da
- 40 CFR Part 60, Appendix B; Proposed Performance Specifications Tests 2 and 3; October 10, 1979 Federal Register.
- 40 CFR Part 60, Appendix F; Proposed Draft Quality Assurance Guidelines.

The first citation specifies the unit performance standards and delineates the use of continuous monitors and/or fuel analyses to demonstrate conformance to these standards. Citations two and three provide minimum performance criteria which must be met throughout the continued use of the system.

It was GCA's intent for the monitoring system to routinely operate in an automatic mode. During the test period, an onsite operator was present to handle routine maintenance tasks and interaction with plant personnel on a daily basis and to obtain the unit operating schedule.

Activities, both routine and nonroutine, were specified in an operations protocol. The protocol was a guide for the operator and other project personnel involved in the conduct of the total program. The full intent of the protocol was to maintain a standard operating procedure and to form a constant feedback loop between the site operator and GCA project management.

Control of program documentation was of significant importance throughout the duration of the program. The site operator was required to maintain a daily operations log book which catalogued all occurrences during the program. In addition, a maintenance log was kept which documented all maintenance activities, both routine and nonroutine. These records were later used to prepare the section of the Final Report discussing the operational problems associated with the monitoring system during the demonstration phase of the program. In addition, these records were used to determine the costs associated with the monitoring system operation and data reporting.

In the specified CEM system, every effort was made to automate as many of the regulatory reporting and operating requirements as possible. The data acquisition/control system (DAS) was configured to provide this automatic control. A block diagram of the DAS concept is shown in Figure 10. The DAS can be divided into two parts: an automatic data logging and control system, and an analog (chart recording) backup recording system. A flow diagram of the planned Daily System Operation is shown in Figure 11.

The automatic section of the DAS included a Central Processor Unit (CPU), a Telephone Modem, Magnetic Data Storage, a Line Printer and an Interactive Keyboard. The CPU received all data and system status signals and effected data storage, data tabulation and system control. Communication with the system was accomplished through the Interactive Keyboard. The operator was able to call for data and fault tabulation or effect system commands through simple keyboard inputs. Correspondingly, a hard copy output in report format was available from the line printer. Long term data storage was accomplished using a magnetic storage media. A telephone modem was included to allow for remote telemetering of all data to GCA system personnel for validation and for remote operation of the system for additional statistical analysis or data manipulation. Also, the remote terminal aided in troubleshooting problems which arose during the course of the program. The in-station CPU processed all data while the remote terminal was used to access the data for nonroutine and quality assurance functions.

On a monthly basis, stratification and abbreviated relative accuracy tests were conducted to demonstrate the continued reliability and accuracy of the data. Proposed Quality Assurance Protocols require either a quarterly relative accuracy test or a standard gas performance audit. No requirements for stratification tests exist other than the initial probe placement specifications outlined in proposed PST 2 and 3. These tests were conducted monthly in order to provide a sufficient data base.

Planned reporting activities included the preparation of hourly and daily average reports on a monthly basis and the quarterly subpart Da emissions report. Of these three reports, the utility operator is required to submit only the subpart Da emissions report. Briefly stated, subpart Da requires that the data for SO_2 and NO_x be reported on a quarterly basis. During each calendar quarter, each average 24-hour period, and a 30-day rolling average up to and including the last day in the quarter must be reported. In addition to these data, a 30-day rolling average pollutant reduction is reported. All data reported which were not calculated utilizing at least 18 hours of data per day is to be so designated, the reasons for the reduction in the data set explained, and the corrective action taken. Data obtained by manual methods and the incidence of analyzer outage must also be designated. Any modifications to the monitoring system must be reported and all possible ramifications fully explained.

Quality Assurance summaries were prepared generally on a monthly basis. These reports presented the results of stratification and relative accuracy tests and monthly precision estimates. The relative accuracy tests and precision estimates are draft Appendix F requirements.

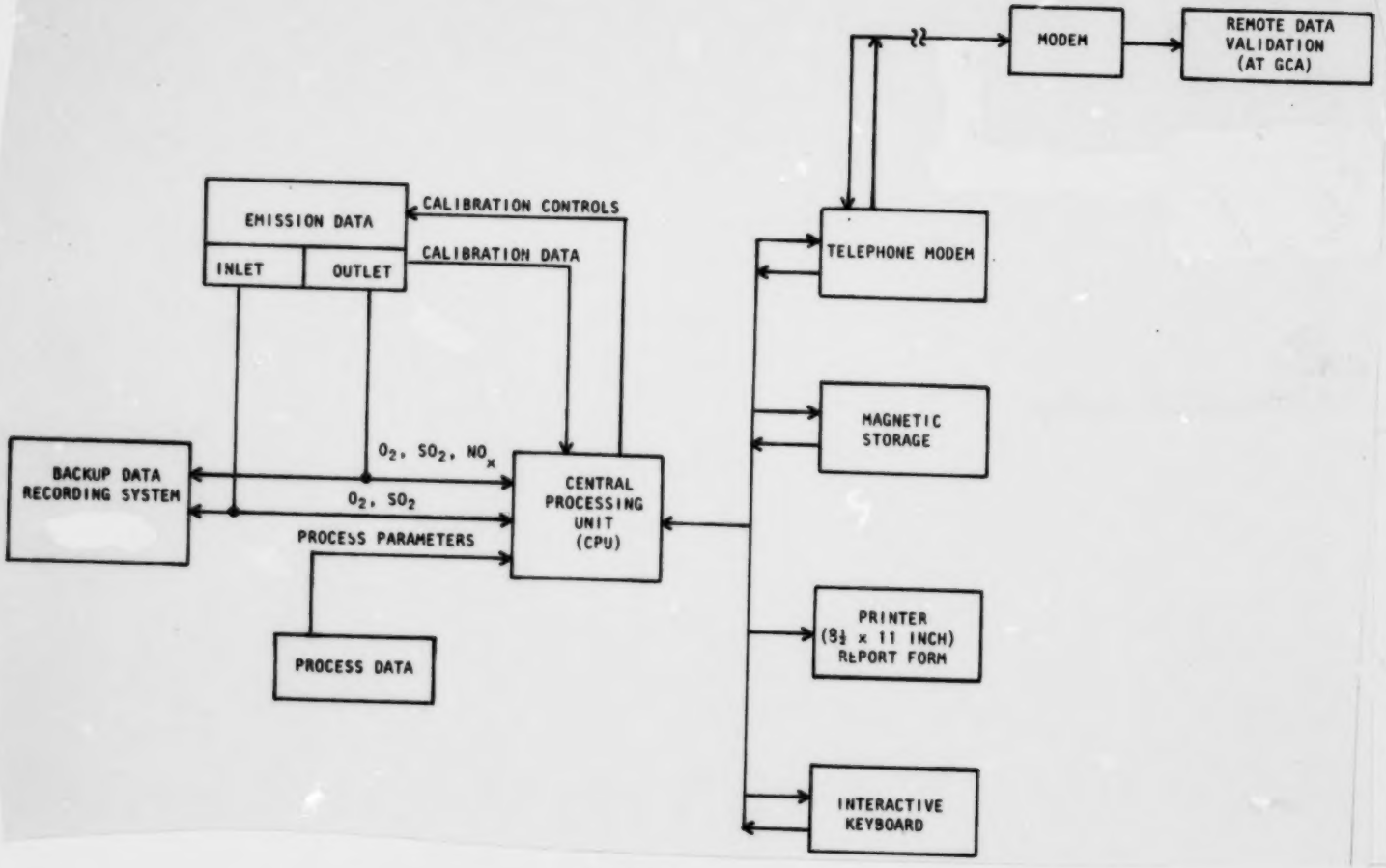


Figure 10. Data acquisition system.

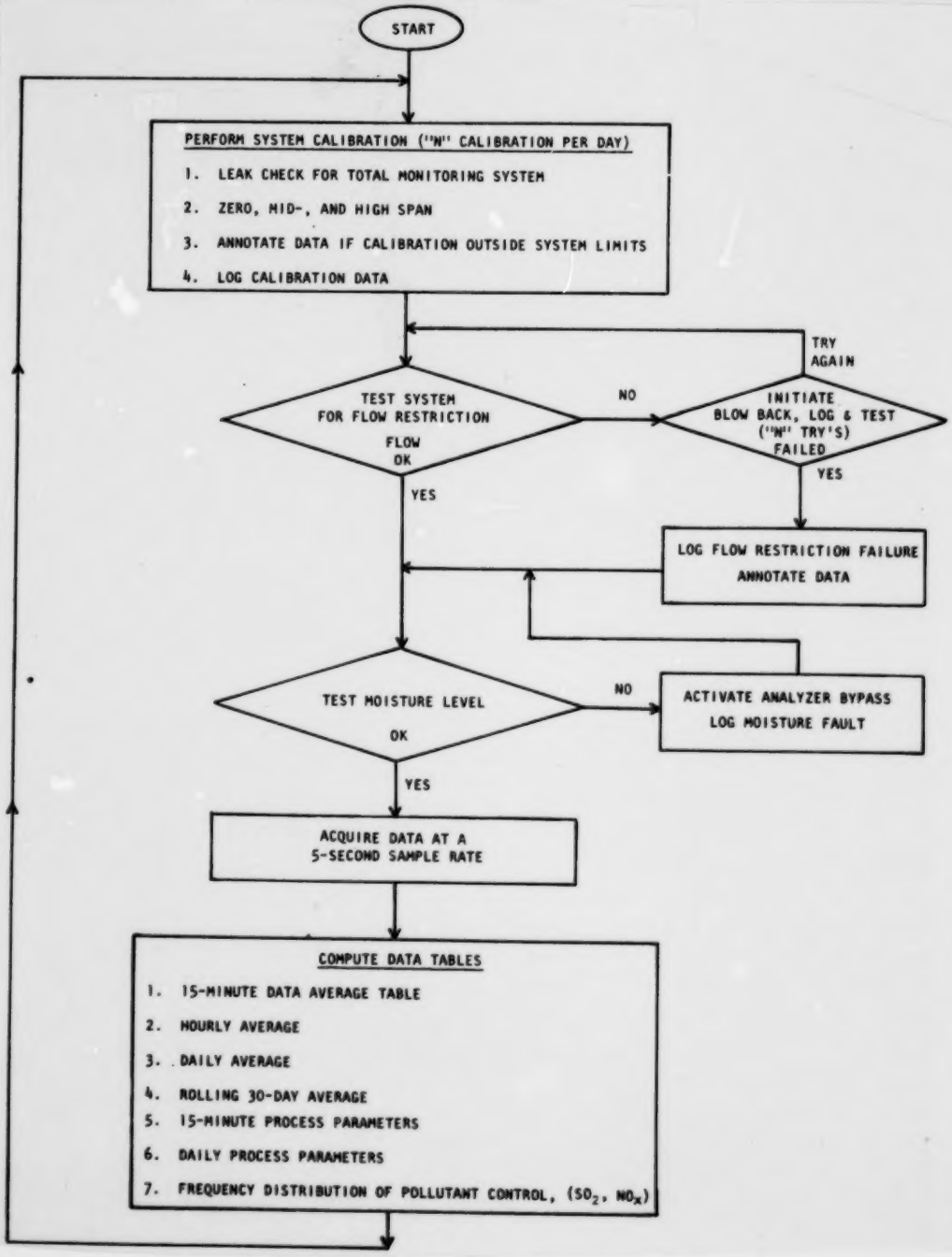


Figure 11. Daily operation algorithm.

All data and operator notations were placed in various site logbooks and individual personal notebooks. Operator logbooks contained day to day occurrences and also the number of man-hours expended in various operational areas. These areas include data acquisition, scheduled and unscheduled maintenance, quality assurance and data reporting.

PHASE IV--DATA EVALUATION

The final phase of the study involved an evaluation of the data. The objective of the evaluation was to determine the instrument system performance and conformance to minimum reporting requirements. In addition, the economics associated with this monitoring system were evaluated. Specifically, the data were evaluated for the following topics.

- Conformance to minimum subpart Da monitoring and reporting requirements.
- Total valid data capture for the entire monitoring period.
- System performance in reference to PST's 2 and 3 and Draft Appendix F.
- Economic issues which include capital costs associated with procurement and manpower costs for operation, maintenance and quality assurance.

Other discussions pertain to the monitoring experience noted throughout the total program.

SECTION 4

CONTINUOUS MONITOR SYSTEM OPERATIONS AND DESCRIPTION

The overall design objectives for the CEMS were to meet subpart Da monitoring and reporting requirements with minimal manpower requirements. To meet subpart Da requirements, the following CEM capabilities were required:

- Dual Inlet FGD Emission Monitoring for SO_2
- Outlet FGD Emission Monitoring for SO_2 and NO_x
- Daily Emission and Removal Efficiency Average Calculations, and
- 30-Day Rolling Averaged Emission and Removal Efficiency Calculations.

These requirements were met with a system approach entailing automatic CEMS operation.

The operational considerations in keeping with the objective of minimal operator attention were as follows:

- Sensors for determining inlet SO_2/and diluent concentration with a single set of sensors and time-shared sampling between the two inlet locations.
- Sensors for determining outlet SO_2, NO_x and diluent
- Automatic Data Acquisition
- Automatic Analyzer Calibration
- Automatic Data Reporting
- Automatic CEMS Problem Detection (fail-safe capability)

Monitoring points as shown in Figure 12 were located at each scrubber module inlet and at the combined outlet breaching prior to entering the stack. At the inlet to each scrubber module, a single sample probe was located downstream of the ID fans and just upstream of a guillotine bypass

damper door. The inlet ducts have inside dimensions of 18 feet 2 inches (width) by 13 feet 7 inches. Each inlet sample probe was located in a reference test port 6 feet from the top of the duct and extended 9 feet into the duct.

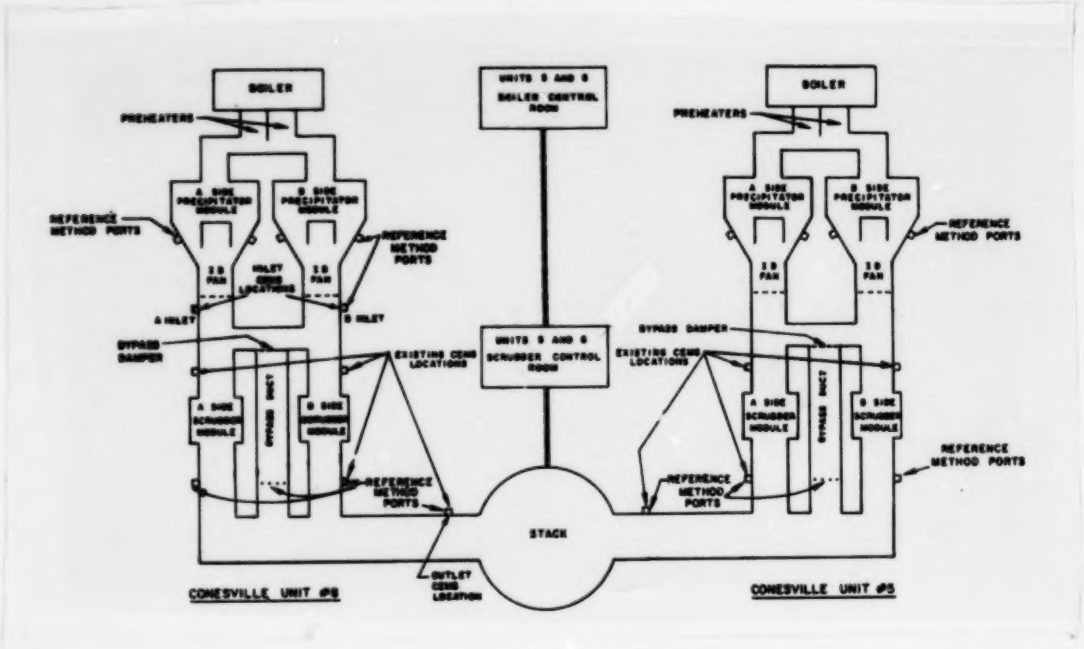


Figure 12. Plan view of Conesville Units 5 and 6

A single outlet sampling point was located in the common breaching downstream from both the scrubber module and bypass duct outlets. The outlet breaching duct inside dimensions are 11 feet 9 inches in width and 26 feet in height. The probe was located in a reference test port 13 feet from the top of the duct and extended 6 feet 6 inches into the duct.

CEMS CONFIGURATION

The multilocation extractive system, shown schematically in Figure 13, was specified by GCA and designed and constructed by KVB, Inc. of Irvine, California. The system consisted of the two sets of gas sensors and associated conditioning hardware and data acquisition equipment as listed in Table 2. One set of instruments was dedicated to the inlet measurements of SO_2 and O_2 on a time-shared cycling basis, and a second set for measuring outlet concentrations of SO_2, O_2, and NO_x. Samples were conditioned by filtering particles using an in-stack filter and those not removed by the in-stack filter by a high-surface area, glass fiber filter also located at the

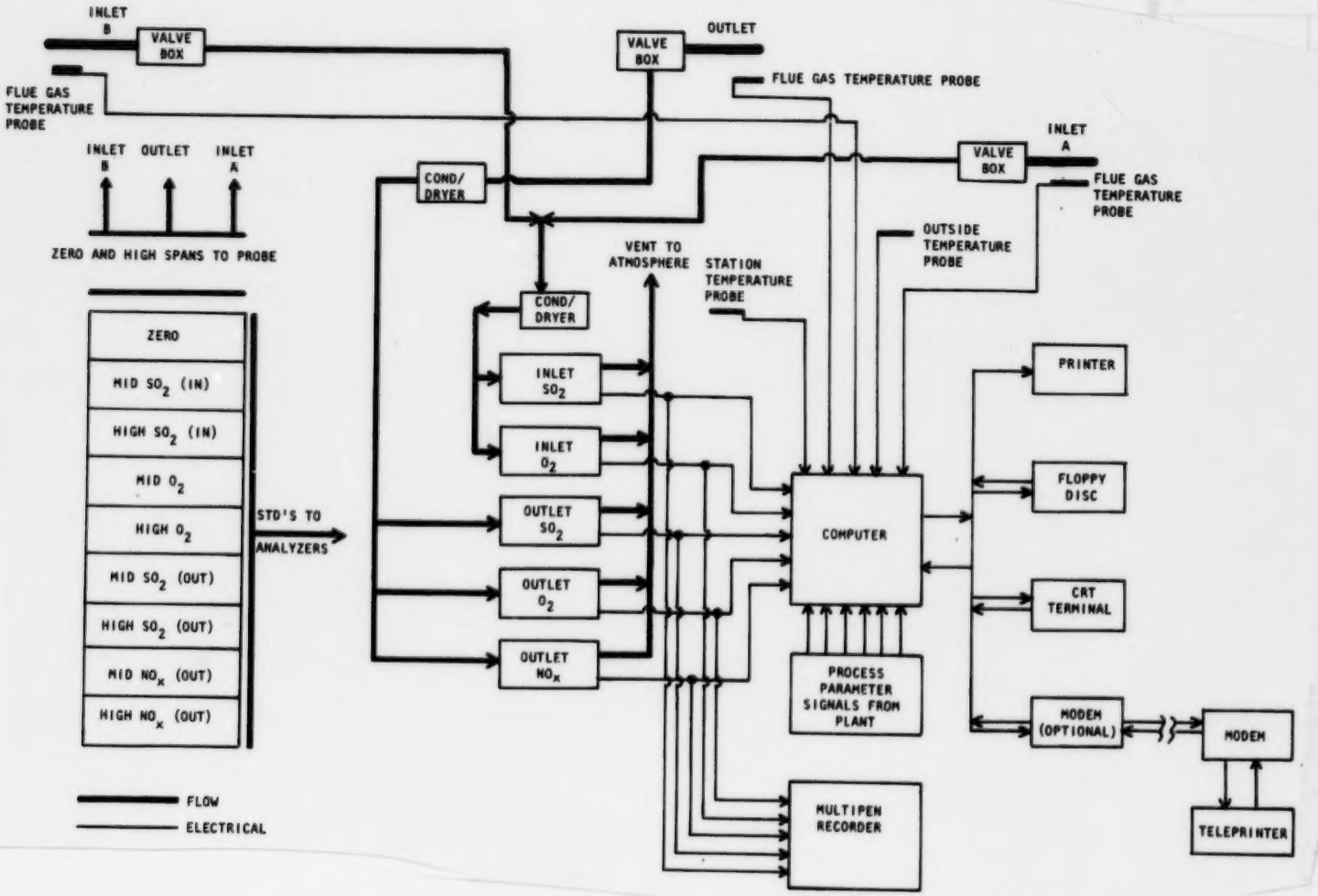


Figure 13. Conesville monitoring system block diagram.

extraction point. A dual pass condensation unit located in the instrumentation shelter removed moisture. The KVB system was designed to operate automatically including multipoint calibrations, zero/span checks, automatic data acquisition, and onsite data reporting.

In the following subsections, the conditioning, sensor and computer systems are discussed in greater detail.

Sample Extraction and Conditioning System

Figures 14 and 15 show schematic diagrams of the inlet and outlet sample extraction and conditioning systems. The general sample gas conditioning sequence was as follows: flue gas extracted at the probe passed through the sample line for a short distance and entered the valve switching box. The sample gas passed through the secondary particulate filter, exited the valve box and was transported through the sample line to the conditioning system. The sample then made one pass through the condenser under vacuum, through the pump and was pressurized through the condenser for a second pass. After exiting the condenser, it passed through a permeation membrane dryer for final drying and through the distribution system which supplied a flow-regulated sample to each analyzer.

Primary particulate matter removal at the inlet sampling locations was intially acomplished only by use of in-stack stainless steel sintered filters. In the later stages of routine monitoring, these filters were removed due to constant pluggage problems. Primary particulate matter removal was then accomplished using the secondary spun glass filter located in the valve box. The low particulate loading that normally results after a wet scrubber system required no in-stack filter at the outlet location and particulate matter removal was left to the outlet valve box filter.

The heated valve boxes were placed at each sampling location house the hardware and air-operated valves used for 2-point calibrations, audit gas injection, probe isolation and blowback-air injection for sample line and probe purging. The spun glass filter element was also located in the valve box.

Self-limiting, heat-traced, sample lines were used to transport the flue gas from the probes to the valve boxes and subsequently to the conditioning system cabinet. The sample line temperature was controlled at 250°F above ambient and required no temperature controller. Included in the sample line assembly was the calibration gas supply line, instrument air supply line and signal wiring used for valve box control.

The sample acquisition system was equipped with fail-safe capabilities which included vacuum and pressure switches and a conductivity sensor for each sample gas flow path. All three of the sensor outputs were wired into the computer to provide visual alarm signals to the CEMS operator on the CRT and fatal alarm signals in which case the computer would automatically terminate the CEMS operation to prevent damage to the sample system or analyzers.

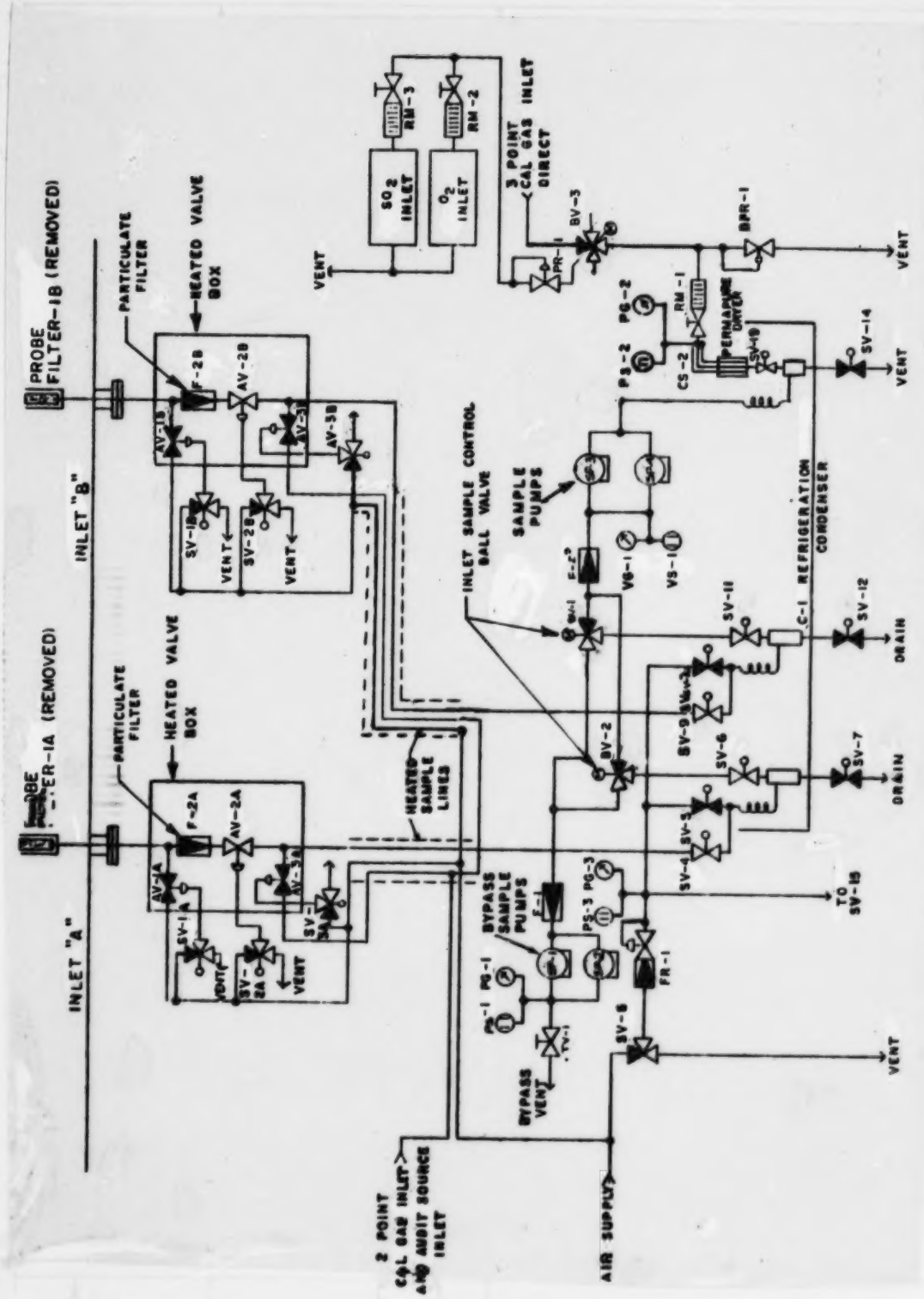


Figure 14. Inlet conditioning system schematic.

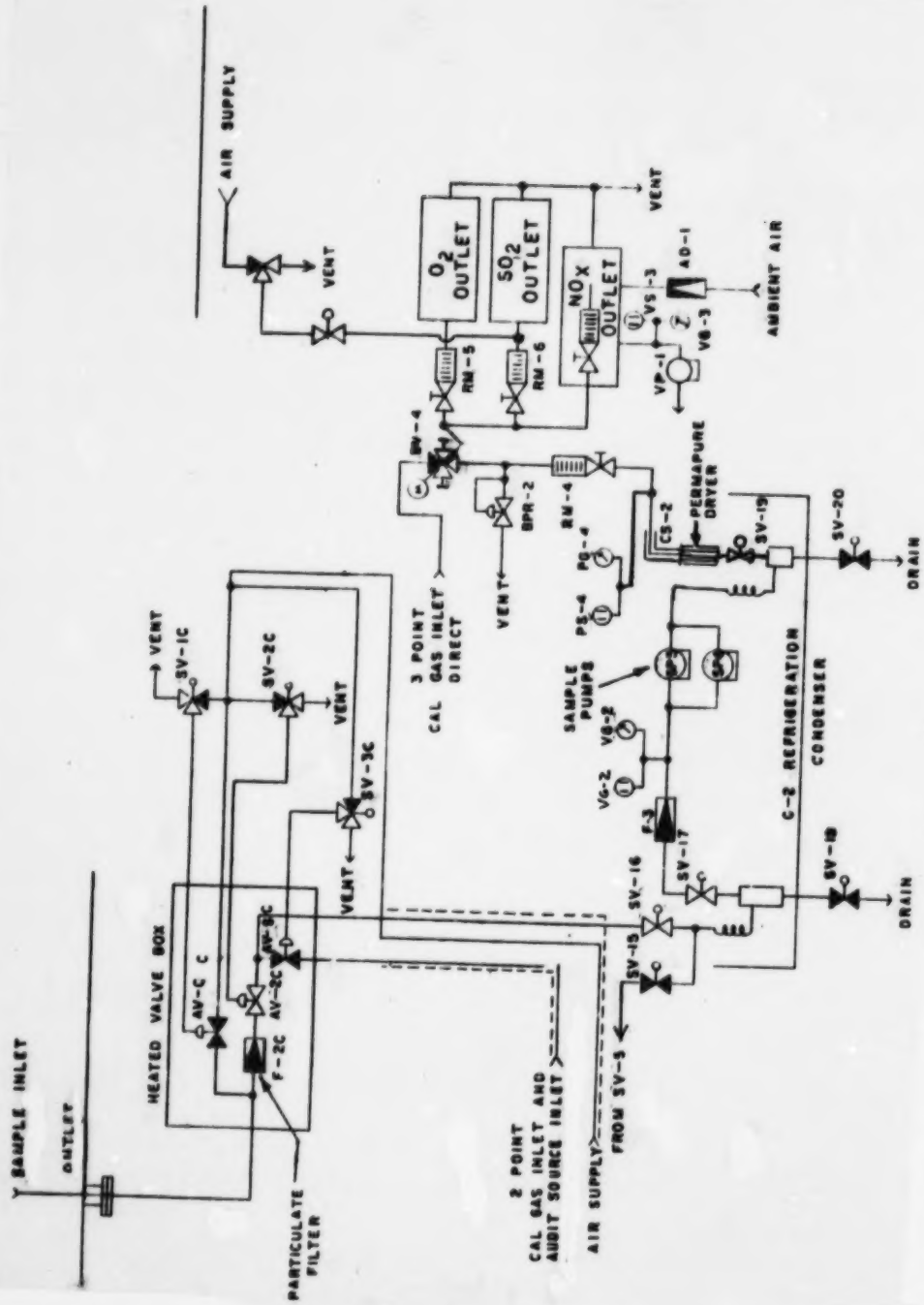


Figure 15. Outlet conditioning system.

Calibration System

The analyzer calibration system design allowed for injection of zero, mid-, and high-span calibration gases directly to the analyzers for 3-point calibrations and for zero and high-span gas injection directly to the stack valve boxes during zero/span, analyzer drift checks. The system also was designed to allow the injection of unknown independent audit gases through the stack valve boxes.

The calibration gas cylinders were located in the computer room adjacent to the CEMS. Solenoid and ball valves located in the analyzer enclosure were used for controlling the automatic calibration sequences. The overall calibration system schematic is shown in Figure 16.

Electronic pressure switches were installed on each gas cylinder line allowing the computer to monitor cylinder pressure. When a cylinder pressure dropped below the minimum allowable use pressure of 200 psi, the CEMS operator would be informed by a message on the CRT.

Analytical Sensors

The CEMS sensors utilized were based on the following detection principles and were operated in the ranges listed below:

Location	Parameter	Instrument	Range	Detection Principle
Inlet	Sulfur Dioxide	DuPont 400	0-5000 ppm	Nondispersive Ultra-violet
	Oxygen	Thermox WDG-III	0-25 percent	Electro Chemical
Outlet	Sulfur Dioxide	DuPont 400	A. 0-1000 ppm B. 0-5000 ppm	Nondispersive Ultra-violet
	Oxygen	Thermox WDG-III	0-25 percent	Electro Chemical
	Oxides of Nitrogen	Thermo Electron 10AR	0-1000 ppm	Chemiluminescent

Both the inlet A and B sample streams were analyzed on a time-shared basis by the single set of inlet analyzes listed above.

The analyzers used for inlet and outlet sulfur dioxide measurements were the nondispersive ultraviolet type. The measurement technique employed is based on the differential absorption of light in the ultraviolet region of the spectrum. Sulfur dioxide is detected at 280 nm and a reference wavelength in the visible regions is monitored to account for matrix absorption. The analyzer voltage output varies proportionally with sulfur dioxide concentration.

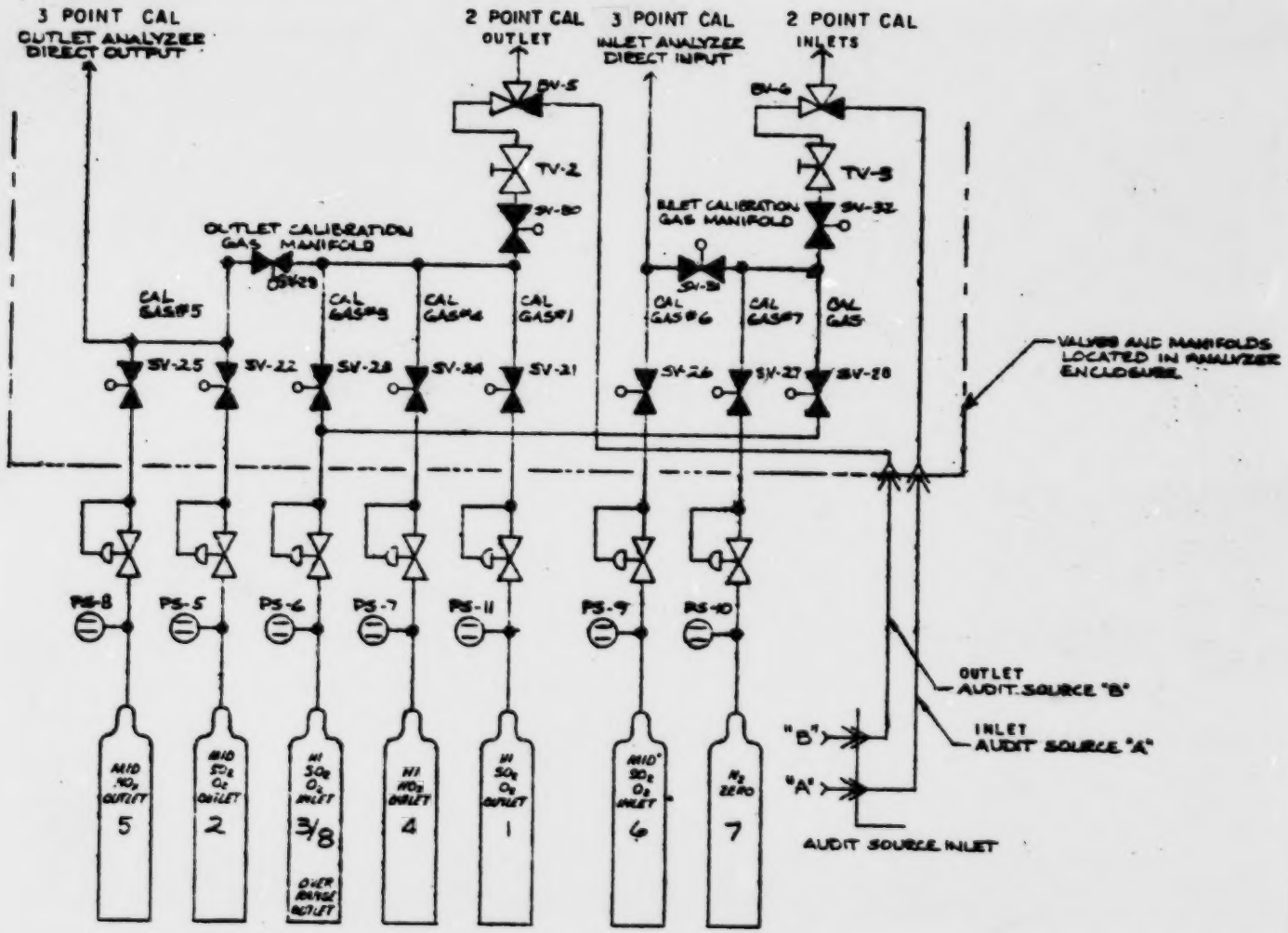


Figure 16. Analyzer calibration system schematic.

The outlet SO_2 analyzer was equipped with an automatic range changing capability. This allowed monitoring of outlet SO_2 emissions during all Unit No. 6 operating conditions from full scrubber operations to full scrubber bypass conditions. The low to high range change level is selectable by keyboard input. The auto range function was controlled by the computer via an electronic solid state relay located in the DuPont 400 control unit.

The outlet SO_2 analyzer was equipped with an automatic zero air system after the first 4 months of operation. At the end of the normal 15-minute sampling cycle, instrument air was injected directly into the instrument. The computer-controlled a servomotor on the zero potentiometer and automatically adjusted the pot until a zero reading was obtained. The automatic-zero function took less than 3 minutes and did not interfere with analysis of the outlet gas sample during normal sampling routine. The automatic-zero system was installed after the analyzer exceeded the 24-hour zero drift test criterion during the initial certification test. This system was effective in maintaining daily zero drift within the acceptable limit.

Two electro-chemical type analyzers were employed for the measurement of inlet and oulet oxygen concentrations. The detector element consists of a closed end zirconium oxide cell. When the cell is heated red hot to a specific operating temperature, it becomes a conducter of electricity in the form of oxygen ions. A voltage output is produced that is logarithmically proportional to the difference in oxygen concentration (partial pressure) between the reference side of the cell (ambient air) and the measurement side of the cell (sample gas). Proper cell temperature is maintained with a resistance temperature detector (RTD), temperature controller and cell furnace.

Oxides of nitrogen were measured at the outlet location using the chemiluminescent principle of NO_x detection. This measurement principle is based on the chemical reaction of ozone and nitric oxide which produces NO_2 molecules at an elevated energy state. Upon return to the ground energy state, the NO_2 molecules emit light, the intensity of which is proportional to the nitric oxide concentration. This light output is detected with a photomultiplier tube which produces a current proportional to the number of NO molecules. Since NO_2 does not react with ozone, the NO_2 in the sample is converted to NO by passing the sample stream through a heated, stainless steel, catalytic, NO_2 to NO converter. In this way total oxides of nitrogen (NO and NO_2) are measured. The reaction of NO and ozone take place in a reduced pressure chamber at near zero absolute pressure.

The Cromemco System Three microcomputer controlled all CEMS functions necessary for automatic operation and reporting. The computer used digitial signals for hardware control and acquired analog signals from the analyzers and process instrumentation during normal date aquisition. The computer program automatically calibrated, sampled, drained the condenser, reported system status and reported process and emission data. The overall computer system configuration is shown in Figure 17.

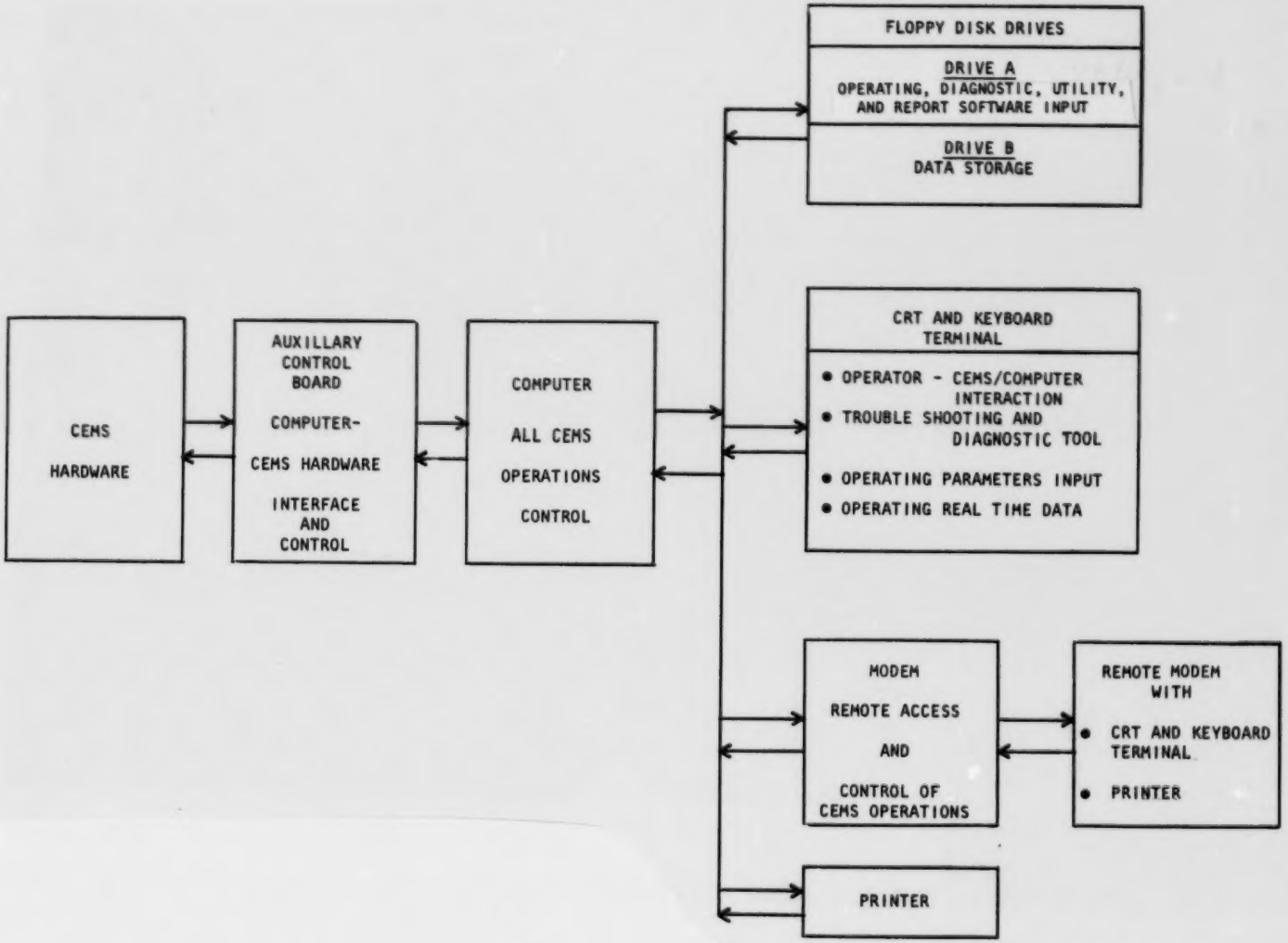

FLOPPY DISK DRIVES
DRIVE A
OPERATING, DIAGNOSTIC, UTILITY, AND REPORT SOFTWARE INPUT
DRIVE B
DATA STORAGE
CRT AND KEYBOARD TERMINAL
• OPERATOR - CEMS/COMPUTER INTERACTION
• TROUBLE SHOOTING AND DIAGNOSTIC TOOL
• OPERATING PARAMETERS INPUT
• OPERATING REAL TIME DATA
CEMS HARDWARE
AUXILLARY CONTROL BOARD COMPUTER-CEMS HARDWARE INTERFACE AND CONTROL
COMPUTER ALL CEMS OPERATIONS CONTROL
MODEM REMOTE ACCESS AND CONTROL OF CEMS OPERATIONS
REMOTE MODEM WITH
• CRT AND KEYBOARD TERMINAL
• PRINTER
PRINTER

Figure 17. CEMS computer system configuration.

The dual disk drives served two separate functions. Disk Drive A was used to input the operating, diagnostic and reporting software into the computer memory. The second disk drive was used for all data storage including process, emissions and calibration data.

The CRT and keyboard terminal provided the basis for operator interaction with the computer system and CEMS. Using the keyboard the operator could initiate 2- and 3-point calibrations, audits, print various reports, troubleshoot and diagnose CEMS problems as well as observe "real-time" process and emissions data. The keyboard was also used to input the operating parameters required by the computer to perform all CEMS functions as well as emissions calculations. These major parameters included:

- Calibration span gas concentrations
- Probe purge frequency
- Automatic 2-point calibration frequency
- Automatic 3-point calibration frequency
- Calibration drift alarm limits
- Outlet SO_2 analyzer auto range level
- 2-Point drift alarm limits
- F-Factors for automatic emissions calculations

The modem provided remote access to the CEMS through the computer. The majority of computer and CEMS operations that are performed onsite could be performed offsite using the modem and a remote CRT keyboard terminal. Using a remote printer, online daily emissions and process data reports could be be printed. The modem was also used to monitor CEMS operations for those periods when the operator was not onsite.

The auxiliary control board located in the conditioning system cabinet provided the interface between the computer and CEMS hardware. All solenoid and ball valves were activated for CEMS operations through the auxiliary control board. Digital signals were sent by the computer to electronic relays in the auxiliary control board which would in turn activated the required hardware. Manual switches enabled manual functioning under the maintenance request routine used in troubleshooting.

SYSTEM OPERATION

Data Acquisition and Reporting

All process, emissions and calibration data were acquired by the computer and stored on floppy disk. Process and emissions data were scanned at 10-second intervals and averaged for each 15-minute sampling cycle. At the

conclusion of the 15-minute cycle, the computer automatically calculated the inlet and outlet SO_2 emission rates, outlet NO_x emission rates and SO_2 scrubber removal efficiency. All 15-minute process and emissions averages were permanently stored on disk and used later for report generation. The single 8-inch floppy disk stored up to 30 complete days of process emissions, calibration data and alarm data.

Emissions and process data reporting was fully automatic and computer controlled. In addition to the ongoing 15-minute process and emissions data summaries, all daily CEMS status changes and other status inputs were reported as well. These included the system diagnostic alarms and results of any 2- or 3-point calibrations. A daily environmental log report was printed out each midnight. The log contained all daily 15-minute process and emissions data averages and results of any calibrations that occurred.

Emissions and process data reports could be printed using the offline reporting software. These reports were selectable in the following averaging times:

- 15-minute for selectable monitoring periods
- Hourly for selectable monitoring periods
- "N" hourly for selectable monitoring periods
- Daily for selectable monitoring periods
- Subpart Da 30-day rolling average
- "N" day rolling average

Figures 18 and 19 are examples of 15-minute log output and hourly averaged report using the reporting software. Except for the daily environmental log report, all other report generation could be carried out only with the CEMS offline.

CALIBRATION ROUTINES

Two- and 3-point calibrations were automatically performed at selectable frequencies. In addition, either calibration routine could be initiated at the start of a 15-minute cycle by keyboard input to the computer. The results from each calibration were printed out at the completion of the function.

During 3-point calibrations, the span gases were injected directly to the analyzers bypassing the conditioning system. Based on the analyzer responses for each zero, mid- and high-span calibration gas injection, a zero difference and span ratio were calculated for each analyzer. The values were expressed as the zero difference from nominal, as a percentage of full scale and as the span ratio to nominal value. The span ratio to nominal value is the average of the slopes of the two lines drawn from the intercept through the mid- and

PERFORMANCE AND TEMPERATURE

LOAD	--FLUE GAS TEMP DEG C--			--MODULE FLOW--		LIQUOR PH		BYPASS DUCT	--SLURRY FLOW--		SO2 RE	STATION	AMBIENT
MW	INLET A	INLET B	OUTLET	A KACFM	B	A	B	PRESSURE	A KGPM	B	PCT	TEMP DEG C	TEMP DEG C
409.1	175	175	50	479.6	411.3	2.50	5.90	6.1	37.80	10.15	74.2	34.3	21.9

EMISSIONS

FAN A	FAN B	BLK A	BLK B	AUD IN	----------INLET---------- PPM SO2	PCT O2	E SO2	SO2 RANGE	BLK C	AUD OUT	----------OUTLET---------- PPM SO2	PPM NOX	PCT O2	E NOX	E SO2
					2980.0	6.81	3093.36	1			759.2	225.5	6.97	170.17	797.10

Figure 18. 15-minute process and emission summary.

EMISSION DATA TABLE

Date of data	Time of data	Boiler load (MW)	Inlet			Outlet					R.E. % of SO_2	Critical codes for this time period
			ppm SO_2	% O_2	ESO_2	ppm SO_2	ppm NO_x	% O_2	ENO_x	ESO_2		
06/01/81	01:00	226.1	2209.1	9.9	2927.6	168.4	203.5	9.3	185.13	213.14	92.7	00000000
06/01/81	02:00	226.0	2244.1	9.9	2972.4	186.8	205.1	9.4	187.21	237.19	92.0	00000000
06/01/81	03:00	226.5	2271.3	9.8	2981.1	178.4	203.4	9.3	184.31	224.93	92.5	00000000
06/01/81	04:00	226.8	2314.1	9.8	3038.3	505.4	205.4	9.3	185.39	631.95	79.2	00000000
06/01/81	05:00	225.9	2332.0	9.8	3059.7	194.1	215.1	9.3	195.28	245.18	92.0	00000000
06/01/81	06:00	227.4	2284.4	9.8	3005.1	204.4	181.7	9.3	165.31	288.60	91.4	00000000
06/01/81	07:00	336.7	2567.5	8.2	2946.7	455.3	251.3	7.7	200.17	299.15	83.1	00000000
06/01/81	08:00	403.5	2743.3	7.6	3024.3	901.5	266.5	7.3	205.89	968.83	68.0	00000000
06/01/81	09:00	404.2	2733.3	7.9	3063.1	868.7	273.2	6.9	205.75	910.06	70.3	00000000
06/01/81	10:00	405.7	2798.9	7.9	3137.4	859.1	277.6	6.8	207.38	892.71	71.5	00000000
06/01/81	11:00	406.8	2843.5	7.8	3176.0	910.5	273.3	6.8	208.65	943.96	70.3	00000000
06/01/81	12:00	404.2	2836.8	7.8	3198.3	945.3	253.9	7.5	198.73	1030.10	67.8	00000000

TEMPERATURE AND PROCESS DATA TABLE

Date of data	Time of data	Boiler load (MW)	Flue gas temp. (C)			Module flow rate		Liquor pH		Bypass duct press	R.E. % of SO_2	Temp. in cent.		Critical codes for this time period
			In. A	In. B	Outlet	Duct A	Duct B	Inlet	Outlet			Station	Ambient	
06/01/81	01:00	226.1	142.5	151.3	58.3	401.2	408.0	2.5	5.9	5.3	92.7	23.6	12.5	00000000
06/01/81	02:00	226.0	144.3	152.0	58.5	399.8	407.4	2.5	5.9	5.2	92.0	23.3	11.1	00000000
06/01/81	03:00	226.5	144.3	151.8	59.0	398.2	408.9	2.5	5.9	5.1	92.5	23.2	11.0	00000000
06/01/81	04:00	226.8	143.9	151.6	76.3	313.5	311.9	2.5	5.9	3.4	79.2	23.0	10.9	00000000
06/01/81	05:00	225.9	143.1	152.1	59.5	400.1	409.1	2.5	5.9	5.2	92.0	23.0	10.8	00000000
06/01/81	06:00	227.4	144.6	151.1	59.5	403.2	409.8	2.5	5.9	5.3	91.4	23.0	10.8	00000000
06/01/81	07:00	336.7	147.8	139.4	66.7	472.6	442.6	2.3	3.9	3.9	83.1	22.7	11.5	00000000
06/01/81	08:00	403.5	184.8	174.1	88.4	473.2	423.6	2.5	5.9	7.1	68.0	22.6	14.1	00000000
06/01/81	09:00	404.2	163.6	175.4	87.5	487.4	437.0	2.5	5.9	7.6	70.3	22.2	16.0	00000000
06/01/81	10:00	405.7	169.4	175.8	85.2	493.3	441.1	2.5	5.9	7.8	71.5	22.7	18.7	00000000
06/01/81	11:00	406.8	170.6	176.3	86.2	434.2	431.1	2.5	5.9	7.5	70.3	23.1	19.0	00000000
06/01/81	12:00	404.2	229.2	176.3	94.4	478.6	423.1	2.5	5.9	7.3	67.8	23.6	23.4	00000000

Figure 19. Hourly average emission and process data report example.

high-span points. Figure 20 graphically illustrates how the calibration curve was constructed. All raw analyzer data were corrected by the latest 3-point span ratio and zero difference prior to permanent storage on disk.

During two-point calibrations, only the zero and high-span gases were injeted into the heated valve boxes at each sampling location. The calibration gases flowed through the entire conditioning system excluding the probe and short connecting line between the probe and valve box. The purpose of the two-point calibration was fivefold: (1) to check for conditioning system leaks, (2) to check for zero and span drift, (3) to provide inputs for the analyzer drift alarms, (4) to allow for quick assessment of data quality, and (5) to provide the inputs for Draft Appendix F precision estimates.

A separate zero and span drift were reported for each inlet and outlet location. The zero and span calibration results were reported as the percentage of span and zero drift from the last valid 3-point span ratio and zero difference value. If zero or span drift exceeded the specified drift alarm levels, than a new 3-point calibration was activated by the operator to set up a new span ratio and zero difference value. The drift alarm levels were set at 5 percent during normal operations. Figure 21 shows a typical 2-point calibration printed.

ROUTINE OPERATION

A CEMS operator was onsite most of the time Unit 6 was online during the field demonstration period to perform daily diagnostic checks, maintenance and logistical support services for CEMS operations. In keeping with the approach of minimal operator attention, the CEMS operator was brought home and the CEMS status was check remotely using the modem link. The modem link was also used when an operator was inadvertantly not onsite during Unit 6 outages when there was a change in the operating schedule of Unit 6.

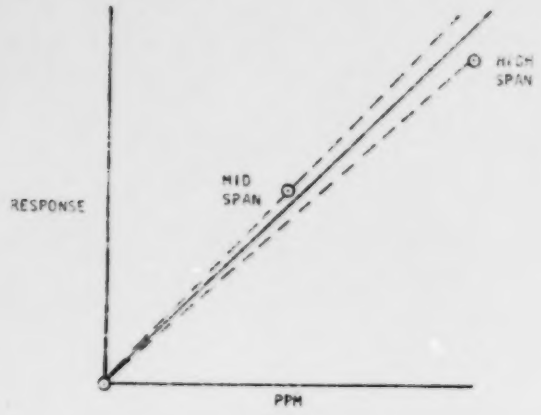
In general, daily, weekly, and monthly operator routines involved performing CEMS diagnostic checks, checking analyzer calibrations, generating daily reports, performing routine and nonroutine maintenance, computer operations and general administration duties, including project documentation and logistical support.

If any CEMS problems were discovered or if the CEMS have been rendered inoperable during the night, the operator would troubleshoot, isolate and correct the problem. Subsequently the CEMS was restarted before performing any other duties.

CEMS Diagnostic Checks

The CEMS diagnostic checks were performed twice a day. This sequence was comprised of visual checks of various CEMS operating parameters such as sample flows, vacuums, pressures and temperatures, to ensure that all were within optimum operating limits. This ensured that the CEMS was performing satisfactorily. A diagnostic checklist was developed during the initial startup period to aid the operator with this task. The operating parameters

CALIBRATION ROUTINE



CONSTRUCTS CALIBRATION EQUATION:

$ppm/E = m(R) + b$

CONDUCTED AT ANALYZERS ONLY EXCLUDING TOTAL EXTRACTION SYSTEM

FREQUENCY: SELECTABLE

ANALYZER CALIBRATION REPORT

READINGS FOR EACH BOTTLE AND GAS IN NOMINAL PPM (PCT FOR O2)

	-------INLET ANALYZER-------			------OUTLET ANALYZER LOW RANGE-------				--OUTLET ANALYZER HIGH RANGE--		
GAS	BOTTLE 7	BOTTLE 6	BOTTLE 3	BOTTLE 4	BOTTLE 5	BOTTLE 2	BOTTLE 1	BOTTLE 4	BOTTLE 1	BOTTLE 3
O2	0.1	13.2	20.2	0.2	0.2	13.1	21.7	0.2	21.7	21.5
SO2	229.8	2891.0	4979.6	-13.7	-14.3	539.4	942.2	-6.3	955.5	5000.0
NOX				884.0	518.8	-0.4	10.7	859.6	8.3	-2.1

SPAN RATIO TO NOMINAL, ZERO DIFFERENCE FROM NOMINAL IN PCT FS

---INLET O2--		---INLET SO2---		----OUTLET O2----		----OUTLET SO2---		----OUTLET NOX---		----OUTLET SO2----	
SPAN	ZERO	SPAN	ZERO	SPAN	ZERO	SPAN	ZERO	SPAN	ZERO	HRSPAN	HRZERO
0.990	-0.1	1.023	-235.0	0.954	-0.2	0.979	13.4	0.967	-10.4	0.972	6.1

Figure 20. 3-point calibration equation and printout.

ANALYZER SPAN-ZERO CHECK REPORT: DRIFTS AND LIMITS IN PERCENT

	INLET A O2		INLET B O2		INLET A SO2		INLET B SO2		OUTLET O2		OUTLET SO2		OUTLET NOX		OUTLET SO2 HI	
	SPAN	ZERO	SPAN	ZERO	SPAN	ZERO	SPAN	ZERO	SPAN	ZERO	SPAN	ZERO	SPAN	ZERO	SPAN	ZERO
DRIFTS	-0.3	-0.2	0.2	1.5	-0.2	-0.2	0.2	1.3	-0.6	0.0	4.0	2.8	-0.6	-0.7	-0.0	1.0
LIMITS	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0

Figure 21. 2-point calibration result printout.

were recorded on the checklist to enable the operator to readily see any change in the values which would indicate a problem. This diagnostic check was actually a part of the routine maintenance procedure.

In addition to the daily checks and recording of CEMS flows, pressures and temperatures, daily checks were made at each monitor sampling location to ensure that all valve boxes and sample lines were heating properly. This system of daily operational checks provided the operator with a thorough summary of the CEMS operating conditions and often would lead to the early detection of a potentially serious problem. A good example of this was when the operator noted that the inlet sample pump upstream vacuum was increasing. This was evidence that the probes were plugging and alerted the operator to clean the probes before the vacuum increased enough to trigger a CEMS shutdown.

Data Reporting and Verifications

The daily environmental log reports, printed at midnight, were reviewed and filed. An additional copy was given to the Unit 6 scrubber supervisor. The CEMS operator reviewed the process and emissions data and noted any process upsets such as scrubber malfunctions, and any emissions data invalidations, such as periods when an analyzer was offline for repair or an analyzer was malfunctioning. The time period and nature of process upsets or data invalidations were recorded in the CEMS uptime log.

Documentation

Documentation involved the daily upkeep of all checklists, making entries in the site log book recording analyzer calibrations, and documenting all process upsets and data invalidations. The operator also completed a weekly maintenance summary sheet on which the routine and nonroutine maintenance items performed on the CEMS were recorded.

The major documentation items maintained on site and a brief description of each follow:

- Daily Logbook--general logbook used to record the daily operations, problems and maintenance associated with the CEMS as well as any other pertinent program information.

- CEM System Log--logbook used to record specific CEMS logsticial and operational data. The following sections were included:

  - Calibration Gas Supply Log

  - Daily Span-Zero Checks

  - 3-Point Analyzer Calibrations

  - CEMS Uptime Log

- Weekly Maintenance Summary

- Data Disk Log

Computer Operation

Daily computer operations consisted of simple routines involving CEMS operator computer interactions using the CRT and keyboard. These operations were self-prompting via instructions from the operational software. The basic operations included:

- Generating daily emission and process data reports.
- Verifying CEMS operating parameters input, such as probe purge frequency, calibration gas values, automatic calibration frequencies, and F factor values for emission rate calculations.
- Checking computer clock time.
- Initiating a 2- or 3-point calibration, if necessary.

If an analyzer required recalibration or if troubleshooting or maintenance was needed, operation of the CEMS could be stopped by the operator. Analyzer recalibration and general CEMS troubleshooting were performed by manual operation of the CEMS using the CRT keyboard and the I/O-TEST Software routine to operate values, activate pumps and obtain analyzer analog outputs. These operations were done using the instructions and procedures in the CEMS Maintenance and Operation Manual and the Computer Manual.

Logistical Support

CEMS operating logistical support primarily involved the ordering of calibration gases and spare CEMS parts, returning empty gas cylinders to the manufacturer and performing any other activities required to support CEMS operations.

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SECTION 5

SYSTEM PERFORMANCE RESULTS

INSTALLATION AND STARTUP

The original installation date was delayed due to problems with the final site preparations and delivery of the CEMS. Final site preparations were completed in February 1981 with delivery of the first CEMS components following shortly thereafter. The CEMS was delivered in two separate shipments. The analyzer and conditioning enclosures arrived and were installed in February 1981. The computer system and associated hardware were delivered at the beginning of March 1981. Final wiring and plumbing hookups were completed by the end of March 1981. Routine monitoring started in June 1981 after the operational test period was completed.

While the CEMS was intermittently operational during April and May 1981, there were still design corrections and additional hardware installation required before the CEMS could be made fully operational according to the original design specifications. Hardware and software design modifications were made up until the initiation of the Operational Test Period.

Software design problems were discovered in the operation and control algorithms. The nature of the problems involved the sequencing of the operational protocols required to control all solenoid and motorized ball valve routines necessary to carry out the various automatic CEMS functions. These automatic functions included sample acquisition, 2- and 3-point calibrations, probe purging, condenser draining, audit routines and the automatic calibration error test routine which is activated during performance specifications testing.

If solenoid and ball valves were not activated in the proper sequence during a specific routine, an interruption in sample or calibration gas flow rate would occur. The interruption would cause the CEMS to terminate operations due to the reaction to an internal system alarm. While the major operational software design problems were debugged prior to the operational test period, software problems were continually discovered after routine monitoring had been initiated in June 1981.

There were several design corrections that were made to the system after installation and during the checkout period. The conductivity switches used for sample line moisture detection were relocated to a position downstream of both condenser outlets to provide for a more reliable moisture detection. A

pressure regulator was installed to regulate the pressure of the calibration gas during direct outlet analyzer calibrations. A time delay relay switch was installed and wired to the computer for automatic restart of the CEMS following power outages. The internal computer circuit boards were rewired following the failure of two boards as a result of faulty system grounding. An audio alarm was installed to alert the operator of any fatal alarm conditions requiring immediate attention. Two frequently used motorized ball valves that controlled inlet sampling were replaced with a different type that provided more reliable service under the intended design use.

There were also repeated leakage problems noted with the original particulate filter holders in the valve hot boxes. The original filter holders were constructed of teflon and would frequently leak or actually blow off during probe purging. The high temperatures required in the valve boxes caused the teflon to deform after a short period of time. These holders were replaced with a stainless steel type and the leakage problems were eliminated.

Several hardware component failures were encountered during the startup period. The inlet primary sample pump diaphragm developed a leak and failed. The original diaphragm was made of viton which was replaced by a teflon-viton type that provided longer service life. All other sample pump diaphragms were replaced to prevent any future pump failures. The Grinnel Wier air valve diaphragm on the inlet valve box developed a leak. This valve is responsible for probe isolation during the purging cycle.

Both inlet and outlet oxygen analyzers developed problems during the startup period. During initial analyzer calibrations, all readings were as much as 25 percent lower than the actual mid and high span calibration gas tag values. It was discovered, after verification of the oxygen span gas concentrations, that the sulfur dioxide in the calibration gas mixture actually interferred with the zirconium oxide oxygen detector cell. This was due to the fact that the analyzers were originally adjusted to operate at a temperature of 600°C, a low enough temperature to cause an SO_2 interference with this measurement technique. Cell temperatures were subsequently readjusted to 800°C and the SO_2 interference problems were eliminated.

Another problem encountered with the oxygen analyzers was the continual plugging of the convection loop that routes the flue gas sample to the zirconium oxide cell. The plugging was caused by the corrosion of the stainless steel portion of the convection loop. The corrosion was a result of sulfuric acid formation, which often results from the combustion of high sulfur coal. This plugging problem could not fully be eliminated due to the inherent design of the analyzers. Therefore, weekly convective loop cleaning was integrated into the preventive maintenance routine developed as part of the CEMS operations protocol.

PERFORMANCE SPECIFICATION TESTS

Following the completion of the startup segment of Phase II, the system was certified according to the criteria delineated in 40 CFR 60 (October 10, 1979, Federal Register). Proposed Appendix B outlines the performance specifications tests which are conducted to demonstrate instrument system performance consistent with published regulatory requirements.

The 168-hour conditioning period was conducted from 23-29 May 1981. The CEMS ran through the entire conditioning period without any major problems. There were two hardware changes made to the extractive-conditioning system both of which were planned changes pending arrival of the replacement hardware. The changes consisted of replacing the Teflon filter holders in all heated valve boxes with stainless steel filter holders and installing a new inlet sampling ball valve in the conditioning cabinet.

The Operational Test Period began on 30 May 1981 and was completed on 8 June 1981. Response time tests were only conducted to verify a less than 15-minue response. Since the requirement has been deleted from the new Proposed Performance Specification Test requirements, as delineated in the 26 January 1981 Federal Register, formal response time tests were not conducted.

The results of these performance tests were discussed in the following subsections.

24-Hour Zero and Calibration Drift Test

The 24-hour drift tests were conducted using the automatic 2-point calibration routine in which the calibration gases were injected at each sampling probe location. Since the drift tests were conducted through the entire sampling acquisition system, the results reflect the performance of the entire CEMS. The results of the 24-hour zero and calibration drift tests are listed in Table 9. All analyzers conferred to the 24-hour zero and calibration drift criteria with the exception of the outlet SO_2 analyzer which exceeded both 24-hour drift test criteria in the normal operating range (0-1000 ppm).

As a result of the outlet SO_2 analyzer 24-hour drift test exceedance, an automatic zero system was installed on the analyzer which eliminated the drift problem. Subsequent tests results exhibit performance consistent with the 24-hour drift criteria. The reason for the normal range drift exceedance is related to the autorange function. This function is not accomplished by a reduction in amplifier sensitivity. Instead DuPont utilizes a straight reduction of the amplifier output using a resistance bridge. Since a resistance bridge is utilized to scale the voltage, the noise level (imprecision) is altered by the same magnitude as the signal is changed. As a result, a comparison of between the low range and high range results indicate a difference in the range 4 to 5 times. A DuPont analyzer which is equipped with a normal span range of 1000 ppm and an autorange to a 5000 ppm range is equipped with an amplifier, bandpass filter and optical system designed to

TABLE 9. CONESVILLE 24-HOUR ZERO AND CALIBRATION DRIFT SUMMARY

Parameter	Zero drift (%)	Calibration drift (%)
Inlet A		
SO_2	0.3	2.5
O_2	0.1 (O_2)	0.1 (O_2)
Inlet B		
SO_2	0.8	1.7
O_2	0.2 (O_2)	0.6 (O_2)
Outlet		
SO_2 (normal range)	3.2	6.4[a]
SO_2 (auto range)	0.8	1.6
O_2	0.2 (O_2)	0.2 (O_2)
NO_x	0.8	1.6

[a]Exceeded performance criteria.

operate at 5000 ppm. Due to the DuPont electronic design, the lower ranges often exceed the drift criteria. This deficiency is normally handled by the addition of an automatic zero adjust function which resets the zero every 15 minutes.

The inlet B O_2 analyzer exceeded the 24-hour calibration drift test criteria, but the failure was probably due to a slight problem in the inlet B side conditioning system and not to actual analyzer calibration drift. The inlet A O_2 analyzer met the calibration drift criteria. Both inlets A and B time share the same oxygen analyzer during normal CEMS operations.

2-Hour Zero and Calibration Drift Test

The 2-hour zero and calibration drift tests were conducted using the automatic 2-point calibration routine. The results of the 2-hour zero and calibration drift tests are listed in Table 10. All analyzers complied with both 2-hour drift test criteria.

Calibration Error Test

The Calibration Error Test was conducted automatically for each of the three sampling locations. Initially the analyzers were calibrated by direct input of the zero, mid and high span gases to the analyzers. This procedure is the same as the automatic 3-point calibration procedure. A calibration equation was calculated as previously described. The zero, mid and high span gases were then input randomly at the valve boxes for each sampling location. The gases were passed through the entire extraction system for all three sampling locations.

The results of the calibration error test are listed in Table 11. All analyzers with the exception of the outlet SO_2 analyzer conformed to the calibration error test criterion. The outlet SO_2 analyzer exceeded the mid span test criteria for the normal operating range. Again, this is most likely attributable to the multirange function.

Relative Accuracy Test Results

Relative accuracy tests were conducted during the June 1981 operational test period. At least nine reference method tests were conducted at each sampling location. For each set of relative accuracy tests, reference method tests were conducted simultaneously at both inlet sampling locations. The reference test results were then averaged for each test run and the averaged reference test values for SO_2, O_2 and emission rate were used to calculate the individual analyzer and system relative accuracies. This relative accuracy calculation method was used because the CEMS calculates a composite average for SO_2, O_2 and emission rate from both inlet locations during the normal operations.

TABLE 10. CONESVILLE 2-HOUR ZERO AND CALIBRATION DRIFT SUMMARY

Parameter	Zero drift (%)	Calibration drift (%)
Inlet A		
SO_2	0.1	0.7
O_2	0.01 (O_2)	0.1 (O_2)
Inlet B		
SO_2	0.4	0.9
O_2	0.1 (O_2)	0.2 (O_2)
Outlet		
SO_2 (normal range)	1.0	2.0
SO_2 (auto range)	0.3	0.6
O_2	0.2 (O_2)	0.2 (O_2)
NO_x	0.7	0.9

TABLE 11. CONESVILLE CALIBRATION ERROR SUMMARY

Parameter	Mid span (%)	High span (%)
Inlet A		
SO_2	1.4	0.5
O_2	1.7	1.1
Inlet B		
SO_2	0.9	0.6
O_2	1.5	0.9
Outlet		
SO_2	6.7[a]	1.6
O_2	0.8	2.5
NO_x	2.3	1.2

[a]Exceeded allowable performance criteria.

Table 12 lists the relative accuracy test results obtained during the June performance testing. The results show that all analyzers were below the 20 percent relative accuracy criterion in terms of individual analyzer performance.

TABLE 12. CONESVILLE RELATIVE ACCURACY TEST SUMMARY

	June 1981 (PST)
Inlet	
DuPont SO_2	4.3%
Thermox O_2	0.5% O_2 absolute
System-Emissions SO_2	6.5%
Outlet	
DuPont SO_2	10.9%
Thermox O_2	0.3% O_2 absolute
System-Emissions SO_2	15.6%
TECO NO_x	12.8%
System-Emissions NO_x	15.2%

The inlet and outlet system relative accuracies in terms of the SO_2 and NO_x emission rate (ng/J) were also below the 20 percent relative accuracy criterion.

STRATIFICATION TEST RESULTS

Stratification tests were conducted at the inlet and outlet CEMS monitoring locations prior to the initial certification tests and periodically thereafter during relative accuracy audits. Probe placement tests are required under Proposed Performance Specifications Tests 2 and 3. All three CEMS probe locations did not meet the eight duct diameter downstream or two diameter upstream siting criteria as outlined in EPA Reference Method 1. The purpose of the stratification tests was to verify that the monitor probes were placed at a respresentative point in terms of the average pollutant emission rate.

Stratification tests were conducted utilizing the CEMS with a slight modification. The modification consisted of equipping the system with two probes using a 3-way ball valve at each location. A separate stratification probe and sample line were attached to one part of the valve and the monitor probe to the other. The common outlet was connected to the monitor sample line enabling the use of the CEMS for conducting the stratification test. The monitor probe which was normally located at the centroid of each duct was used as the reference point and each traverse point was sampled using the movable stratification probe. The 3-way valve was switched from one probe to the

other for either a traverse point response or reference point response. All analyzer responses were logged using the computer analog output function. The responses were averaged for each traverse and reference point.

The tests consisted of measuring the SO_2 and O_2 concentration at each of the traverse points. In between each port (3 traverse points/port), the monitoring system was switched from the traverse point to the reference point. The data obtained from the reference point were utilized to correct for temporal process variations that occurred during the test. Temporally corrected traverse data were utilized to define the spatial variability of the flue gas stream.

Figures 22 and 23 illustrate the stratification test grids utilized for the outlet and inlet stratification tests, respectively. The number of traverse points utilized exceeded the minimum number of nine points as delineated in Proposed Performance Specifications Tests 2 and 3 (October 10, 1979, Federal Register).

The stratification test results shown in Table 13 indicate that placement of the inlet A monitor probe at point C-2 provided for representative flue gas sampling in terms of the average bulk SO_2 emission rate. A stratification test was not conducted at the inlet B location due to the low probability of stratification. The duct configurations at both inlet locations are identical. In addition, both locations are situated prior to the scrubber system where the probability of stratification was anticipated to be very low.

The SO_2 emission profiles for all the outlet stratification tests are presented in Table 14. Generally, at full load conditions with both modules online, the SO_2 emission profile exhibits vertical stratification in which the SO_2 concentration increases in magnitude from top to bottom. This same trend holds true with Unit 6 operating at half load with only A Module online. When Unit 6 is operated at half load with only B Module in operation, the SO_2 emission profile generally indicates that a homogeneous gas stream exists throughout the duct. There were large differences in the SO_2 emissions at the bottom of the duct during separate A and B Module operations at half load. These differences indicate a more thorough mixing of the B Module and bypass duct effluents. At the bottom of each column in Table 14, the percent difference of SO_2 emissions between the duct average and the monitor probe location for each test are presented. These results indicate that at full load conditions with both modules online, the probe placement at point F-2 provided representative measurement of the average SO_2 emissions within the duct. The same conclusion holds true for half load operation with only Module B online; however, with only Module A online, the monitor probe placement does not provide a sample representative of the average bulk gas SO_2 emissions as evidenced by the large differences shown in Table 14.

In order to further clarify the outlet stratification as a function of load, tests were conducted with one module online and the unit operating at half load. During these tests, flue gas flowrates were measured through the operating module as well as the bypass duct.

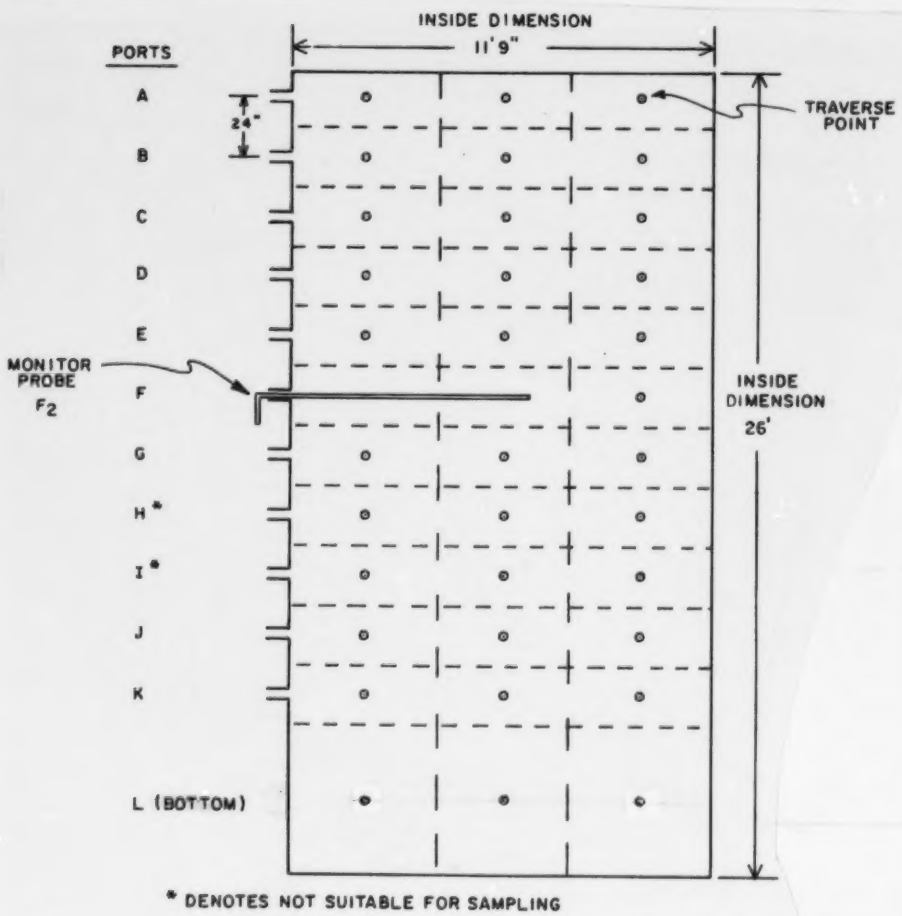


Figure 22. Outlet duct stratification test grid.

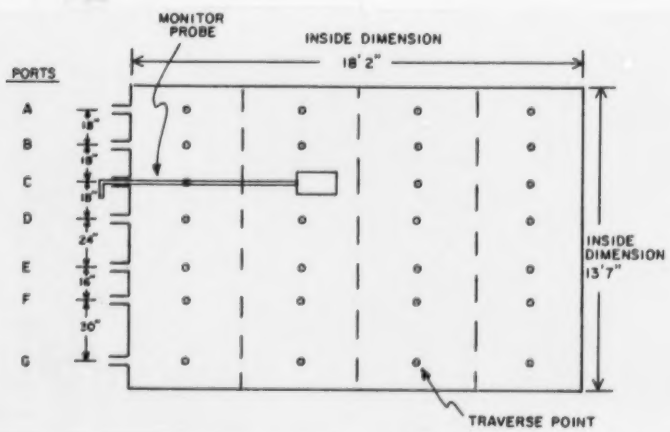


Figure 23. Inlet duct stratification test grid.

TABLE 13. INLET A STRATIFICATION TEST DATA SUMMARY

	Time corrected results ng/Joule			
	Points			
Port	1	2	3	4
A	3276	4321	3298	3357
B	3301	3372	3293	a
C	3373	3294	3339	3340
D	3306	3332	3367	a
E	3252	3251	3225	a
F	3390	3288	3255	a
G	3278	3214	3361	a

Duct avg. all points = 3306

Monitor probe at point C-2

[a]Denotes point could not be sampled.

TABLE 14. OUTLET STRATIFICATION TEST SO_2 EMISSION PROFILE SUMMARY, COLUMBUS AND SOUTHERN OHIO ELECTRIC, CONESVILLE, UNIT NO. 6

	Full load A & B modules				Half load A module		Half load B module	
Port	6/1/81	7/17/81	12/11/81	6/10/82	7/18/81	12/12/81	7/19/81	12/12/81
A-1	474	332	266	161	342	455	1665	1285
2	396	267	284	151	291	390	1738	1312
3	353	230	276	138	304	347	1683	1127
B-1	416	309	191	156	399	395	1697	1241
2	356	309	205	144	323	439	1700	1237
3	331	239	191	162	353	403	1580	1186
C-1	489	366	246	171	470	354	1768	1239
2	364	270	215	166	357	346	1724	1219
3	334	284	222	154	300	336	1580	1214
D-1	626	462	277	164	540	389	1810	1260
2	402	345	226	179	339	327	1837	1214
3	476	323	349	167	257	299	1630	1128
E-1	830	722	394	171	695	305	1830	1259
2	655	447	476	220	326	308	1821	1200
3	607	463	360	199	241	243	1615	1131
F-1	1096	885	326	174	897	583	1835	1233
2[a]	1058[a]	741[a]	374[a]	240[a]	358[a]	358[a]	1849[a]	1232[a]
3	1037	710	506	296	237	276	1779	1141
G-1	1454	1000	510	275	1239	745	1967	1241
2	1587	1046	974	290	773	539	1756	1179
3	1386	1150	725	302	866	313	1569	1170
H-1	1487[b]	1045[b]	750[b]	206	1540[b]	900[b]	1873[b]	1140[b]
2	1661[b]	1142[b]	1000[b]	278	1335[b]	950[b]	1677[b]	1190[b]
3	1605[b]	1210[b]	550[b]	300	1593[b]	725[b]	1457[b]	1110[b]
I-1	1481	1090	850	284	1840	1040	1780	1130
2	1649	1238	1025	326	2063	1200	1599	1180
3	1649	1270	675	297	2321	1225	1345	1100
J-1	1508	1135	608	336	2141	1430	1686	1077
2	1684	1334	1064	375	2708	1523	1520	1224
3	1777	1330	1044	321	3049	1800	1233	1081
K-1	1623	1375	793	387	2629	1216	1478	1204
2	1734	1405	1108	423	3315	2194	1421	1318
3	1438	1464	1039	344	3774	2240	948	1026
L-1	1708[b]	1550[b]	1020[b]	c	3200[b]	1567[b]	1572[b]	1179[b]
2	1853	1581	1107	c	3466	2039	1322	1102
3	1695[b]	1640	1150[b]	c	3600[b]	2158[b]	800[b]	1260[b]
Avg.	1091	853	593	240	1346	843	1615	1164
% Diff.	3%	13%	37%	0%	73%	57%	14.5%	5.8%

[a]Monitor probe location.

[b]Point could not be sampled. Estimated result.

[c]Unit 6 tripped offline.

Table 15 presents the overall stratification test results in terms of system gas flow rate, bypass duct pressure and the effects on the spatial variability of the SO_2 emissions within the outlet duct. The results in Table 15 support the conclusion that at full load conditions with both modules online, the probe placement provides a sample representative of the average bulk SO_2 emission rate and, that calculated scrubber efficiencies are nearly equal using the CEM probe and duct average emission rates.

At half load operation with only A Module online there was a large difference between the monitor probe and duct average SO_2 emission rates. Calculated scrubber efficiencies were much larger using these two averages. At half load operation with B Module online, the probe placement does provide an average representative of SO_2 emissions within the duct. The calculated scrubber efficiencies are again nearly equal.

RELATIVE ACCURACY AUDITS

The draft quality assurance requirements soon to be promulgated as Appendix F specify two procedures for assessing monitor accuracy. These procedures involve the use of certified gas standards or side by side checks using the applicable EPA Reference Method.

On a twice per year basis, the continuous moinitoring system relative accuracy must be assessed using one of the above methods. Based on this proposed requirement, GCA conducted the accuracy checks using the EPA Reference Method option. These accuracy checks were conducted three times during the one year demonstration phase.

The relative accuracy audits consisted of at least six replicates of the applicable reference methods. Methods 3, 6 and 7 were utilized for the determination of O_2, SO_2 and NO_x, respectively. A Method 7 replicate consisted of three separate grab samples. Data obtained from these abbreviated test periods were presented in terms of percent relative accuracy.

Summaries of the inlet SO_2, outlet SO_2 and NO_x relative accuracy audits are shown in Tables 16, 17 and 18. Included in these tables are the number of valid test replicates, the mean difference and the confidence intervals associated with each relative accuracy result. The summaries also contain the results from the initial and final relative accuracy tests for comparative purposes.

The inlet monitor results shown in Table 16 indicate that, in all cases, the SO_2 monitor on a ppm basis and the inlet monitor system on an emission rate basis were well within the specified criterion of less than or equal to 20 percent. Relative accuracies on a ppm basis ranged from 4.3 percent to 11.6 percent and on the emission system rate basis, from 6.5 percent to 15.0 percent.

Although not required, relative accuracies were calculated for the oxygen analyzer. These results are presented on a percent oxygen basis (X+CI). These results ranged from 0.46 percent O_2 to 1.53 percent O_2. When conducting certification tests, it is advisable to evaluate the O_2 monitor

TABLE 15. STRATIFICATION TEST RESULT SUMMARY TABLE CSOE CONESVILLE UNIT NO. 6

Stratification Test	Date	Time	Load MWE	System Gas Flow - DSCFM				Total Gas Scrubbed %	By Pass Duct ΔP In. H_2O	Emission ng/Joule				
				A Module	B Module	By Pass Duct	Total Flow			Inlet E_{SO_2}		Outlet[1] E_{SO_2}	Diff.[2] %	Scrubber[3] Efficiency %
Full load A&B Modules	06/01/81	1730-1939	403	369,589	327,923	388,239	1,085,751	64%	7.5	3268	P	1139	-	65%
											D	1091	4.4%	67%
Full load A&B Modules	07/17/81	1150-1430	409	377,039	322,619	385,093	1,084,751	64%	6.25	3168	P	856	-	73%
											D	853	0	73%
Full load A&B Modules	12/11/81	1944-2230	404	463,075	427,735	347,510	1,238,320	72%	8.0	3413	P	565	-	83%
											D	593	+4.7%	83%
Full load A&B Modules	06/10/82	1640-1907	404	505,592	451,689	49,018	1,006,299	95%	10.4	2875	P	288	-	90%
											D	240	-20%	92%
Half load A Module	07/18/81	0930-1300	221	377,813	-	429,931	799,744	47%	5.0	3805	P	500	-	87%
											D	1346	62.8%	65%
Half load A Module	12/12/81	1815-2115	215	462,686	-	210,799	673,496	69%	7.1	3313	P	317	-	90%
											D	843	62%	75%
Half load B Module	07/19/81	0930-1130	219	-	391,749	383,149	744,898	51%	6.3	3500	P	1909	-	45%
											D	1615	+15.4%	54%
Half load B Module	12/12/81	1025-1315	210	-	416,698	270,853	687,550	61%	6.6	3368	P	1164	-	65%
											D	1187	+2%	65%

FOOTNOTES:

[1]Outlet E_{SO_2}: P = Ave E_{SO_2} at CEM Probe (Reference point) for test duration.
D = Ave E_{SO_2} in Duct, arithmetic average of all points-time corrected.

[2]Diff. % = $\frac{D - P}{D} \times 100$

[3]Scrubber Efficiency calculated using P and D outlet E_{SO_2} values.

TABLE 16. RELATIVE ACCURACY TEST SUMMARY INLET SO_2 CEM SYSTEM, COLUMBUS AND SOUTHERN OHIO ELECTRIC, CONESVILLE UNIT NO. 6

	Individual monitor relative accuracy							CEM system relative accuracy			
	SO_2 monitor (ppm)				O_2 monitor[a]			SO_2 emission rate (ng/Joule)			
Date	No. of valid runs	Mean diff. $\bar{X}$[b]	Confidence interval CI_{95}	Relative accuracy % RA	Mean diff. $\bar{X}$	Confidence interval CI_{95}	Absolute accuracy % O_2	No. of valid runs	Mean diff. $\bar{X}$	Confidence interval CI_{95}	Relative accuracy % RA
June 1981	9	+43	79	4.3	0.29	0.17	0.46 O_2	9	+111	87.3	6.5
July 1981	6	+280	45.8	11.6	0.425	0.128	0.55 O_2	6	+398	50.7	15.0
June 1982	7	-23.71	184.65	6.5	0.47	0.207	0.68 O_2	7	+71.43	180.1	7.8
July 1982	6	-92.6	115.7	7.4	1.19	0.339	1.53 O_2	6	+167.3	91.63	9.4
Aug. 1982	9	+144	23.58	9.8	0.276	0.258	0.53 O_2	9	+193	55	9.8

[a]Results reported in % O_2 absolute ($\bar{X}$ + CI_{95} = % A)

[b]Difference = Analyzer Value--Reference Method Value

TABLE 17. RELATIVE ACCURACY TEST SUMMARY OUTLET SO_2 CEM SYSTEM, COLUMBUS AND SOUTHERN OHIO ELECTRIC, CONESVILLE UNIT NO. 6

	Individual monitor relative accuracy							CEM system relative accuracy			
	SO_2 monitor (ppm)				O_2 monitor[a]			SO_2 emission rate (ng/Joule)			
Date	No. of valid runs	Mean diff.[b] $\bar{X}$	Confidence interval CI_{95}	Relative accuracy % RA	Mean diff. $\bar{X}$	Confidence interval CI_{95}	Absolute accuracy % A	No. of valid runs	Mean diff. $\bar{X}$	Confidence interval CI_{95}	Relative accuracy % RA
June 1981	12	+51.6	48.35	10.9	0.136	0.14	0.28 O_2	9	+82	+72	15.6
July 1981	6	+88	36.4	16.0	0.175	0.224	0.4 SO_2	6	+105.2	34.5	16.9
June 1982	11	-56.6	10.0	13.3	0.056	0.134	0.19 O_2	11	-52.6	12.6	12.8
July 1982	6	+17.9	12.83	12.9	0.04	0.2	0.24 O_2	6	+19.16	15.7	14.2
Aug. 1982	12	-0.1	8.33	3.9	0.13	0.3	0.43 O_2	12	+1.7	8.85	4.8

[a]Results reported in % O_2 absolute ($\bar{X}$ + CI_{95} = % RA)

[b]Difference = Analyzer Value--Reference Method Value

TABLE 18. RELATIVE ACCURACY TEST SUMMARY OUTLET NO, COLUMBUS AND SOUTHERN OHIO ELECTRIC, CONESVILLE UNIT NO. 6

	NO monitor				CEM system relative accuracy			
	Relative accuracy (ppm)[a]				NO emission rate (ng/Joule)[a]			
Date	No. of valid runs	Mean diff. $\bar{X}$	Confidence interval CI_{95}	Relative accuracy % RA	No. of valid runs	Mean diff. $\bar{X}$	Confidence interval CI_{95}	Relative accuracy % RA
June 1981	17	-24.5	10.7	12.8	12	-20.3	13.2	15.2
July 1981	6	+7.7	6.76	6.7	6	+9	6.9	9.7
June 1982	11	25.38	17.93	17.2	11	+19.5	13.07	17.7
July 1982	6	+44.3	15.54	23.7[b]	6	+33.4	+9.8	23.2[b]
Aug. 1982	12	+19.36	5.6	12.7	12	+15.34	6.04	14.8

[a]Difference = Analyzer Value--Reference Method Value

[b]Exceeded 20% Relative Accuracy Criterion

separately in order to determine where inaccuracies may exist. GCA normally utilizes a absolute accuracy criterion of $\leq$0.5 percent O_2. If compared to a reference method test average of approximately 6 percent O_2, this compares to a relative accuracy of approximately 8 percent.

The outlet SO_2 results shown in Table 17 were also within the specified limits. On a ppm basis, relative accuracies ranged from 3.9 percent to 16.0 percent and from 4.8 percent to 6.9 percent based on emission rate .

The performance for the outlet O_2 monitor was not as variable as the inlet monitor. Results ranged from 0.19 percent O_2 to 0.43 percent O_2.

The NO_x results are shown in Table 18. With the exception of the July 1982 test, all results were within the specified limits. On a ppm basis, the relative accuracies ranged from 6.7 percent to 23.7 percent, whereas those based on emission rate ranged from 9.7 percent to 23.2 percent.

The larger than expected relative accuracy result for the July 1982 test was the result of a larger mean difference. The confidence interval was comparable in magnitude to the other tests.

PRECISION ESTIMATES

Data obtained from the daily calibration checks were utilized to estimate the upper and lower probability precision limits for each analyzer. These estimates were determined using the protocol delineated in the Draft Appendix F Quality Assurance Procedures dated 11/19/81.

Using the data generated during the daily zero span checks as the basic data inputs, the upper and lower probability estimates for the zero and high span levels were calculated according to the following equations.

$$d_i = \frac{Y_i - X_i}{X_i} \times 100 \qquad (1)$$

where

Y_i = Monitor indicated concentration from the i-th precision check.

X_i = The precision check reference concentration used for the i-th precision check.

Monthly average percent difference, $\bar{d}_j$, is calculated as follows:

$$\bar{d}_j = \frac{1}{n} \sum_{i=1}^{n} d_i \qquad (2)$$

where

n = number of valid precision checks made during the calendar month j.

The standard deviation of the percent difference (S_j) is calculated as follows:

$$S_j = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} d_i^2 - \frac{1}{n} \left(\sum_{i=1}^{n} d_i \right)^2} \qquad (3)$$

Upper and lower probability limits (UPL and LPL) at the 95 percent confidence limit are calculated according to equations 4 and 5.

$$UPL = \bar{d}_j + 1.96\, S_j \qquad (4)$$

$$LPL = \bar{d}_j - 1.96\, S_j \qquad (5)$$

Precision limits for the daily zero check were calculated using the same equations except that x_i in the denominator of the first equation is assigned the value of the instrument full scale operating range.

The precision estimate results for the entire demonstration phase are shown in Table 19. These estimates for the most part were calculated from entire 30-day blocks of data. The September estimates were calculated using approximately 14 days of data due to the scheduled plant outage which occurred during mid September.

Data for the inlet monitoring system as a whole (all analyzers) exhibited the poorest performance during the period January-August 1982. Span interval ranges were on the order of 20-30 percent while the zero interval ranges were on the order of 5 percent. It is not completely understood why these results are much higher than the outlet except to note that the inlet zero span system was consistently trouble prone. During this cycle, valve sticking would often cause erroneous zero and span data to be generated. GCA had noticed throughout the course of the program that the indicated drift was not normally real and was a result of inaccurate zero/span data. Since the zero/span data are only used as control check checks and not for scaling purposes, the monitoring data, the majority of the time, are valid even though the zero span data indicate otherwise.

Results for the outlet monitors exhibited the best performance during the period May-September 1982 in which all interval ranges for both zero and span were less than 10 percent. Interval ranges for the initial period of June-September 1981 were slightly larger than the last 4 month period occurring in 1982. Much of the lower performance occurred during the June-July time period in which considerable system problems ocurred followed by significant troubleshooting activities.

Results for the outlet SO_2 analyzer show marginal improvement for the span level from the first 4 months of operation to the last 8 month period and a significant improvement at the zero level. An automatic zero control was

TABLE 19. PRECISION ESTIMATE RESULTS SUMMARY CONESVILLE CEMS

		Inlet CEMS probability limits															
		A O_2				B O_2				A SO_2				B SO_2			
		SPAN		ZERO		SPAN		ZERO		SPAN		ZERO		SPAN		ZERO	
Year	Month	UPL	LPL	UPL	LPL	UPL	LPL	UPL	LPL	UPL	LPL	UPL	LPL	UPL	LPL	UPL	LPL
1981	June	2.4	-5.3	0.8	-0.7	3.3	-5.3	3.8	-1.1	6.2	-4.5	2.6	-1.4	10.8	-3.4	4.2	-1.4
	July	1.5	-4.3	1.4	-1.1	15.7	-14.4	2.2	-1.8	2.7	1.0	6.0	3.3	5.5	-9.6	6.8	-3.5
	August	1.5	-11.3	0.8	-0.7	3.6	-11.3	3.4	-2.3	3.6	-5.6	5.3	-1.6	4.3	-5.4	6.9	-2.8
	September	-7.5	-11.7	0.2	-0.3	-2.1	-13.0	5.4	-2.3	9.9	-1.9	15.5	-3.5	16.5	-1.9	13.8	-2.7
1982	January	3.4	-26.7	0.2	-0.1	5.3	-22.7	0.3	-0.3	17.1	-25.5	0.1	-0.9	18.7	-15.6	-0.1	-1.0
	February	-2.9	-9.5	0.2	-0.3	16.6	-29.4	4.7	-4.7	1.7	-6.3	2.2	0.9	13.4	-24.8	7.6	-3.1
	March	-0.6	-6.0	0.2	-0.2	18.1	-26.1	2.2	-2.0	6.5	-18.5	0.8	-1.4	10.4	-29.0	0.4	-1.2
	April	21.1	-25.0	10.7	-12.0	10.3	-20.5	2.9	-1.1	-15.4	-13.8	13.9	-12.1	39.8	-44.9	2.9	-1.6
	May	1.1	-11.3	1.4	0.1	4.5	-6.7	3.0	-0.4	25.5	7.7	13.8	-4.3	13.7	12.7	10.8	-2.7
	June	-0.1	-13.5	1.2	-1.0	-0.4	-12.4	1.9	-1.9	13.6	-1.3	4.2	-0.9	14.3	-3.9	4.3	-1.0
	July	-3.4	-10.0	0.9	-0.4	-3.6	-9.9	1.0	-0.3	10.1	-9.8	3.0	-1.6	10.7	-10.4	3.7	-2.3
	August	3.6	-20.0	0.3	-0.2	3.3	-20.7	1.7	-0.9	14.0	-8.2	4.6	-1.4	13.8	-5.4	4.6	-1.1

		Outlet CEMS probability limits											
		O_2				SO_2				NO_x			
		SPAN		ZERO		SPAN		ZERO		SPAN		ZERO	
Year	Month	UPL	LPL	UPL	LPL	UPL	LPL	UPL	LPL	UPL	LPL	UPL	LPL
1981	June	2.1	-3.8	1.0	-0.6	9.5	-4.4	24.9	-3.0	5.1	-3.8	2.2	-0.9
	July	5.6	-8.5	2.0	-1.7	-13.2	-14.0	4.8	-0.2	10.3	-6.1	1.3	-0.9
	August	7.8	-4.7	1.3	-0.5	13.4	-7.1	11.8	-6.2	4.3	-3.1	1.7	-1.3
	September	0.1	-2.7	0.1	-0.1	6.1	-2.5	3.6	-0.2	9.9	-17.6	1.2	-0.7
1982	January	-3.2	-4.2	0.1	-0.1	4.5	-11.7	3.6	-0.9	19.8	072.6	1.7	-1.5
	February	33.8	-64.7	17.6	-13.7	11.4	-15.5	3.4	-1.5	6.5	65.1	1.8	-1.0
	March	-2.6	-4.1	0.2	-0.3	28.7	-44.7	4.0	-2.3	6.5	-8.9	1.3	-1.0
	April	0.9	-4.4	1.2	-0.9	15.6	-12.2	13.5	-2.1	7.9	-18.9	1.3	-1.3
	May	0.8	0.0	0.0	0.0	4.6	3.7	4.1	2.8	-2.7	-5.2	0.7	-0.9
	June	2.4	-0.9	0.2	-0.2	8.4	-9.3	4.6	-2.4	0.2	-9.7	0.8	-1.5
	July	6.8	-4.4	0.3	-0.2	0.3	-10.7	3.1	-1.3	-7.1	-19.9	1.9	-1.8
	August	4.9	-7.5	0.3	-0.3	7.2	-10.0	2.3	-0.6	19.9	-25.5	1.4	-2.0

UPL = Upper Probability Limit

LPL = Lower Probability Limit

installed during September 1981 to reduce zero drift. The zero control automatically readjusted the zero value every 15 minutes during the conditioning system condenser blowdown cycle. This addition was made in order to meet the 24-hour calibration drift criteria.

FINAL PERFORMANCE SPECIFICATIONS TEST

During the last month of operation, an abbreviated performance specifications test series was conducted. This consisted of a full relative accuracy test and a repeat of the calibration error test.

The results of the August 1982 test are shown in Tables 20 and 21. All results were well within the allowable criteria. Relative acuracy results indicated performance consistent with past tests.

TABLE 20. AUGUST 1982 CALIBRATION ERROR TEST RESULTS

Location	Analyzer	Pollutant	% calibration error	
			Mid	High
Inlet A	DuPont	SO_2	4.7	3.1
Inlet B	DuPont	SO_2	4.0	4.7
Inlet A	Thermox	O_2	3.8	3.7
Inlet B	Thermox	O_2	2.2	2.6
Outlet	DuPont	SO_2	4.6	2.2
Outlet	Thermox	O_2	1.0	2.4
Outlet	Thermo electron	NO_x	3.8	1.5

TABLE 21. AUGUST 1982 RELATIVE ACCURACY TEST RESULTS

Location	Analyzer	Pollutant	Relative accuracy
I	Pont	SO_2	9.8%
	Thermox	O_2	0.53% O_2
	DuPont/Thermox	E_{SO_2}	9.8%
Outlet	DuPont	SO_2	3.9%
	Thermox	O_2	0.43% O_2
	DuPont/Thermox	E_{SO_2}	4.8%
Outlet	Thermo electron	NO_x	12.7%
	Thermo electron/Thermox	E_{NO_x}	14.8%

SECTION 6

DISCUSSION OF RESULTS; AVAILABILITY AND COSTS

CEMS AVAILABILITIES

CEMS availability has been calculated in terms of both the overall availability on an hourly basis for the emissions and efficiency parameters and in terms of Subpart Da reporting requirements. When calculating the availabilities in each of these areas, all available data were included where no known problems existed that affected the data such as, conditioning system problems. Also if data were not stored on the disk due to a data acquisition problem, the 15 minute computer printouts were used to supplement the data collected during that particular time period. Additionally periods of data were also included where the 3-point calibration results were incorrectly calculated due to a computer problem despite all cal gas readings being correct. When this occurred, the reported emissions data would also be incorrect even though all analyzers were functioning properly. Provisions were not available in the reporting program to manually calculate the analyzer calibration factors for each analyzer and apply these to correct the data. If this option was available, these data would be available for reporting purposes.

Overall availability was determined on a monthly basis and is based on a relative percentage of total Unit 6 operational hours for each month of the demonstration phase. The availabilities were calculated as a straight percentage of total Unit 6 operating time. These reported availabilities provide an indication of overall monitoring system performance for the demonstration phase.

The CEMS has been broken down into four separate subsystems and for calculating availability. The four monitoring subsystems that comprise the CEMS are:

- Inlet SO_2 Emissions Monitoring System
- Outlet SO_2 Emissions Monitoring System
- Outlet NO_x Emissions Monitoring System
- SO_2 Removal Efficiency Monitoring System

The SO_2 removal efficiency system consisted of the simultneous monitoring of both inlet and outlet SO_2 emissions.

In order to evaluate CEMS performance relative to the Subpart Da reporting criteria, the minimum data capture rates for the CEMS were calculated with adherence to Subpart Da requirements. Subpart Da requirements specify that for every 30 successive 24-hour boiler operating days a minimum of 22 days of valid monitoring data is required. A valid day of data is based on a minimum data capture of 18 hours of data in each 24 hour boiler operating day. Furthermore, only two 15 minute periods of actual data capture are required for an hour of data to be valid. A boiler operating day is specified as a day in which the boiler is in operation for the entire 24 hour period, commencing at midnight and terminating the following and night.

The Subpart Da availability and data capture results were calculated based on these criteria. The periods of Unit 6 operating times were divided into successive 30-day periods. Availabilities were then determined for each monitor subsystem for each 30 day period.

Hourly Availability Results

The CEMS hourly availability and data capture results are tabulated in Table 22 and Figure 24. The overall availabilities for the 13 month demonstration phase for inlet SO_2, outlet SO_2, outlet NO_x and removal efficiency were 75 percent, 78 percent, 65 percent and 75 percent, respectively. The simultaneous availability for all emissions parameters was 62.5 percent. The 12 month results excluding December 1981, were slightly higher and approached 80 percent for inlet SO_2, outlet SO_2 and removal efficiency monitor systems. The simultaneous availability of all parameters was 67 percent while the outlet NO_x monitor system availability was slightly higher at 70 percent.

The reason for the lower NO_x monitor system availability was due primarily to the extremely low availability of 22 percent experienced in March 1982. This low availability was attributed to persistent problems with both the analyzer vacuum pump and NO_2-NO converter.

The availabilities for each emission parameter followed the same general trend during the demonstration phase. As expected CEMS availability was higher during the first month of operation in June 1981. A sharp reduction in availability was experienced in July of 1981 when the CEMS room air conditioners failed which caused computer and auxiliary control board problems due to the extremely high room temperatures. The problems encountered during this period required a site visit by a vendor service technician to restore the CEMS to full operational status.

Following repair of the CEMS, availabilities exceeded 80 percent for all parameters during August and September 1981. During mid September, the CEMS was shut down for a scheduled Unit 6 outage. The outage lasted through the early part of December.

Unit 6 was brought back online during the first week in December. December availabilities were extremely low due to intermittent CEMS operation which resulted from a variety of startup problems. These problems were

TABLE 22. CONESVILLE CEMS OVERALL AVAILABILITY AND DATA CAPTURE JUNE 1981-AUGUST 1982

	Unit No. 6 uptime hours			CEMS hardware availability hours			All parameters hours			Inlet E_{SO_2} hours			Outlet E_{SO_2} hours			Outlet E_{NO_x} hours			SO_2 removal efficiency hours		
Month	Days	Total	Avg/ day	Total	Avg/ day	%	Total	Avg/ day	%	Total	Avg/ day	%	Total	Avg/ day	%	Total	Avg/ day	%	Total	Avg/ day	%
1981																					
June	27	648	24	600	22	93	565	21	87	565	21	87	576	21	89	576	21	89	565	21	87
July	24	528	22	386	16	73	290	12	55	298	12.4	56	364	15.2	69	364	15.2	69	298	12.4	56
Aug	26	591	22.7	530	20.4	90	478	18.7	81	504	19.4	85	511	19.7	86	478	18.4	81	502	19.3	85
Sept	12	270	22.5	263	22	97	218	18.2	81	228	19	84	218	18.2	81	218	18.2	81	218	18.2	81
Dec	24	552	23	244	10.2	44	75	3.1	13.6	193	8	35	207	8.6	37	93	4	17	193	8	35
1982																					
Jan	25	573	23	462	18.5	81	460	18.4	80	460	18.4	80	460	18.4	80	460	18.4	80	460	18.4	80
Feb	18	409.5	23	330	17.5	80	277	14.7	68	330	17.5	80	325	17.3	79	277	14.7	68	325	17.3	79
March	29	676	23.3	576	19.9	85	150	5.2	22	563	19.4	83	567	19.6	84	150	5.2	22	563	19.4	83
April	21	454	21.6	422	20	93	367	17.5	81	408	19.4	90	378	18.2	83	383	18.2	84	378	18.2	83
May	8	182	23	92	11.5	51	58	7.2	32	58	7.2	32	92	11.5	51	92	11.5	51	58	7.2	32
June	16	348	23	270	17	78	260	16.2	75	260	16.2	75	270	17	78	270	17	78	260	16.2	75
July	22	509	23	445	20.2	87	429	19.5	84	445	20.2	87	435	19.8	85	429	19.5	84	435	19.8	85
Aug	25	560	22.4	464	18.6	83	322	13	58	423	17	76	438	17.5	78	343	13.7	61	423	17	76
Total 13 mos.	277	6300		5070	18.3	80.5	3936	14.2	62.5	4721	17	75	4828	17.4	77.6	4120	14.9	65	4721	17	75
12 mos.[a]	253	5748		4826	19	84	3861	15.2	67	4528	18	79	4621	18.3	80	4027	15.9	70	4528	18	79

[a]Excludes December 1981 restart period.

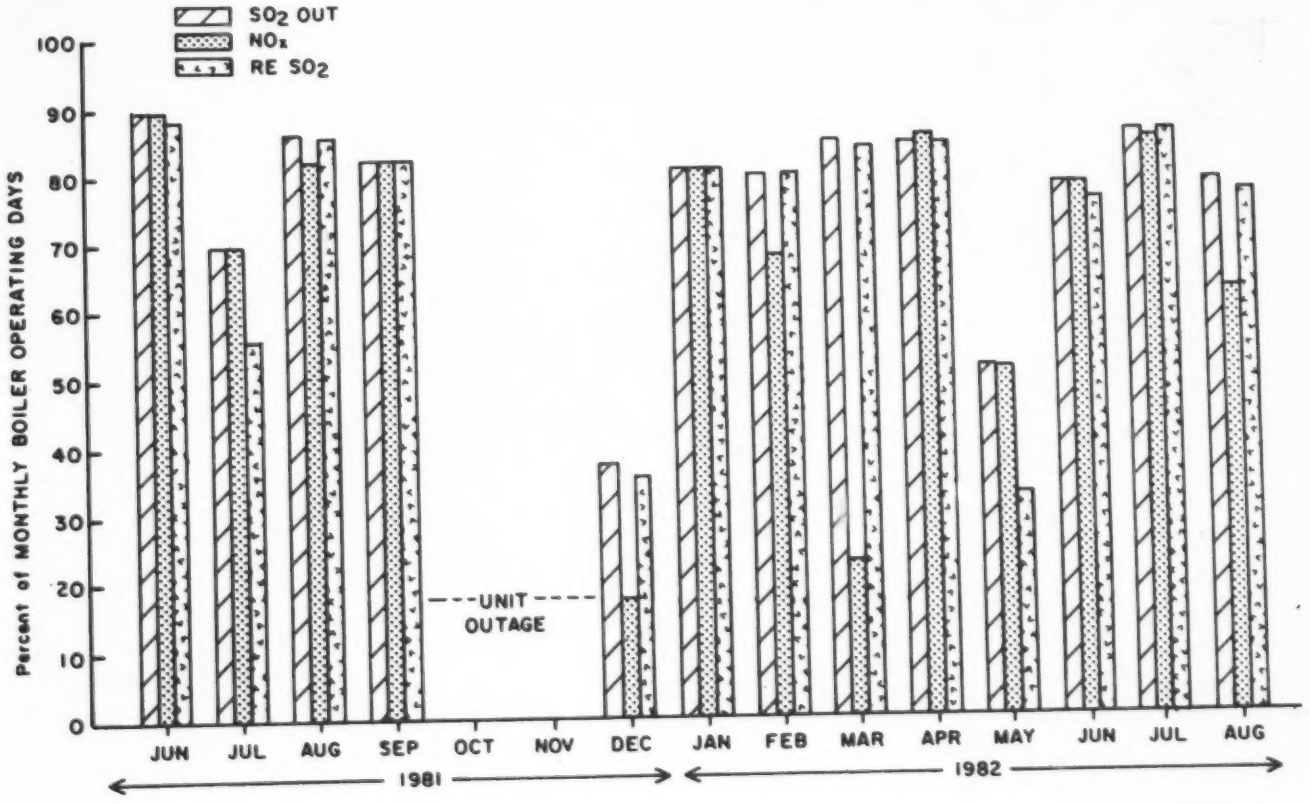


Figure 24. Monitoring data availability by calendar month for outlet SO_2 and NO_x emissions rates and sulfur dioxide removal efficiency (percentage of CEMS Uptime relative to total boiler uptime hours.)

attributed to the long period of time in which the CEMS was not in service and unanticipated conditioning system problems which resulted due to the cold weather.

Following the December monitoring period, availabilities returned to levels experienced prior to the Unit 6 outage. With the exception of the extremely low availability for the NO_x system during March 1982, CEMS availabilities remained at or near 80 percent until May 1982 when problems were experienced with the inlet conditioning system. The low relative up time is due to the intermittent operation of Unit 6 in May; that is if one day of malfunction was experienced, the relative availability compared to Unit 6 was greatly effected. Repairs were effected during May 1982 to restore the CEMS to full operational status.

June availabilities were 75 percent or better for all parameters and probably would have been higher had Unit 6 been in operation for the entire month. CEMS availability peaked in July of 1982 just over a full year after the start of the demonstration phase. For the last month of operation availabilities dropped off again due to conditioning system problems on the inlet and again for the NO_x system due to vacuum pump problems.

The last availability to be discussed is the CEMS hardware availability which is also tabulated in Table 22. The CEMS hardware availability is the general operational availability of CEMS in terms of inlet and/or outlet conditioning system operation. The availability represents the time when there were no major conditioning system hardware or compuer problems when the CEMS would be incapable of operating such as in the case of the computer disk drive failures, read errors, and operating system problems. The difference between the hardware availability and each emission parameter availability and data capture would be due to problems such as a leak in the conditioning system, an analyzer problem, an invalid calibration, and routine maintenance downtime.

Availability was also reduced because of uncertainties in the Unit 6 operating schedule. When the unit was scheduled for an extended outage, the CEMS operator was called home, but left the CEMS running. If Unit 6 stayed online or came back online before scheduled, a CEMS operator would often not be immediately available to return to the site. When this occurred, the condition of the CEMS was checked using the modem link. If a computer system problem occurred, the modem link could not be used and if the CEMS developed a conditioning system problem, the operator would have to return to the site in order to restore the CEMS to operational status. Delays were experienced by the CEMS operator in returning to the site resulting in extended downtime periods and hence decreased availability. These factors further contributed to the low availabilities for the December 1981 and May 1982 periods.

Subpart Da Availability Results

Availability has thus far been defined as a ratio of time when the CEMS is recording valid data to the boiler operating time. Subpart Da further modifies the definition of availability to include the following provisions:

- two 15 minute average data points (50 percent or more) constitutes a valid hour
- 18 hours or more of valid data per boiler operating day (75 percent) constitutes a valid day
- 22 valid days per 30 boiler operating days (73 percent) constitutes a valid 30 day period.

A boiler operating day is defined as the midnight to midnight period when the boiler operates for the entire 24 hours. These provisions represent an overall data capture rate of 27 percent (50 percent of 75 percent of 73 percent) however this would only be true if good and bad days of data occur in a fairly specific order. For example, 10 down days in a row would provide higher availabilities than 10 down days each spaced 1 day apart. In the first case, the first two 36 day rolling averages would not meet Subpart Da requirements whereas in the second case the first 4 data points would not meet Subpart Da requirements. In both cases, the overall availability for the 30 day period is the same. Subpart Da availabilities digress further from true availability in that incomplete 24 hour boiler operating days are not counted and times when the CEMS are available and the boiler is not operating are also not counted. The apparently low data capture requirements are actually quite strict in the sense that 1 down day can affect up to 30 rolling averages.

In this program, Subpart Da availability reports were to be generated by the computer data system. Due to various software problems, Da availabilities have been calculated by hand with the following results:

- 177 periods of 30 successive boiler operating days
- 119 periods of acceptable SO_2 emissions data (67 percent)
- 109 periods of acceptable NO_x emissions data (62 percent)
- 104 periods of acceptable SO_2 removal efficiency data (59 percent)

These availabilities represent the times when Subpart Da requirements for 30 day rolling average emission rate/removal efficiency could be calculated by the computer. The average emission rates are not available due to problems with the software as discussed in later sections. The above availabilities were calculated using the daily emissions reports and the uptime log book notations. The emissions reports provide the number of valid hours obtained by the CEMS each day as well as an indication of the validity of the data. The uptime log further clarifies data validity questions as well as providing boiler operating times.

CEMS Problems and Downtime Summary

Because of the difficulty in discussing downtime as a function of the complete integrated system, downtime has been broken down into three separate systems corresponding to the following individual CEMS monitoring areas:

- Inlet SO_2 Emission Monitoring System,
- Outlet SO_2 and NO_x Emissions Monitoring System, and
- Computer System.

This multisystem approach has been taken so that major problem areas which contributed most to CEMS operational downtime and invalid data periods for the individual emission parameters can be readily identified.

Inlet and Outlet Monitoring System Problems--

Inlet and outlet monitoring system downtime has been divided into two basic categories:

- Conditioning System Problems
- Analyzer Problems

The category of conditioning system problems included: hardware failures, system leaks, probe blockage, condenser problems and any associated problems such as water in the sample lines as a result of a condenser isolation solenoid valve failure; or continued CEMS operation under a read error or computer operating system problem.

Hardware failures consisted of ruptured valve box diaphrams, faulty solenoid valves, and corrosion failure of the inlet probes. Conditioning system leaks were usually associated with the hardware failures as in the case of air valve diaphrams and the inlet probes. System leaks were also attributed to corrosion failures in the conditioning system fittings, especially at the probe/sample line and sample line/condenser connections. Corrosion of other conditioning system components namely the inline pressure and vacuum switches also occurred.

Solenoid valve failures were also experienced. The solenoid valves were used for calibration gas control and condenser isolation among other functions. The failures were the result of the filter valves and valves seats which deformed after repeated use. This deformity caused the valves to stick during operation.

The failure of a calibration gas solenoid valve during a 2-point calibration would result in a CEMS crash due to interuption of the sample gas flow rate. The failure of a condenser isolation solenoid valve caused reentrainment of water in the sample lines due to insufficient condenser blowdowns and led to both hardware corrosion problems and analyzer problems. Inlet probe pluggage was a very common problem despite regular probe cleaning. Pluggage occurred more frequently during the colder winter months and during times when Unit 6 was brought offline. During unit outages, the CEMS was left in operation in case Unit 6 was brought online and no operator was onsite. During the Unit 6 outages the probes cooled as the probes were only heated from the flue gas. When the unit was brought back online, the moisture from the flue gas would condense in the probes until the probes were

brought up to the normal operating temperature. Consequently, the probes plugged as a result of this moisture combining with particulate matter in the probes thereby forming a solid plug. The CEMS could not be restarted until the probe was cleaned which was often delayed until the operator arrived on site.

Another problem that affected the conditioning system was attributed directly to cold ambient temperatures. This problem resulted from the formation of ice plugs in the condenser drain, analyzer, and back pressure relief exhaust lines. The ice plugs prevented normal condenser drainage and created excessive back pressures in the analyzers due to the flow restrictions. As a result, the moisture would be entrained in the sample lines down stream of the condenser leading to hardware corrosion and subsequent shutdown of the CEMS due to excessive back pressure. This problem was corrected by the installation of a common heated exhaust line manifold.

Analyzer problems consisted of both component failure and operational problems. Component failures included: sensor cells, RTD or furnace failure in the oxygen analyzers, lamp and/or lamp power supply failure in the sulfur dioxide analyzers and vacuum pump failure in the NO_x analyzer. Operational problems consisted of plugged convective loops in the oxygen analyzers, dirt deposits in cell windows in the sulfur dioxide analyzers; and, internal capillary, NO_2-NO converter flow blockages and vacuum pump gasket problems associated with the NO_x analyzer. Dirty cell windows in the sulfur dioxide analyzers and plugging problems in the nitrogen oxides analyzer were the result of conditioning system problems which allowed the injection of a slightly moist sample gas.

Computer System Problems--

Computer system problems have been divided into these four individual categories:

- Read Errors
- Operating System Problems
- Software Problems
- Hardware Failure

Read error and operating system problems were a frequent occurence throughout the routine monitoring phase. These problems resulted in the CEMS becoming inoperational in the sense that all computer controlled sampling operations were suspended, i.e., probe purges, condenser blowdowns and time shared sampling at the inlets. However, the CEMS sample pumps would still be operating but data were not acquired.

These two problems contributed to the conditioning system problems as mentioned in the form of sample line moisture problems, and probe blockage due to lack of condenser blowdowns and probe purges. For these reasons, emissions data even if acquired on a back-up data logger or recorder could not be

considered valid. Read errors and operating system problems also prevented remote access to the CEMS and computer using the modem link when the CEMS operator was off site. CEMS status checks could not be made or the noted problems corrected until the operator returned to the site.

Read errors occurred when the disk drive head was unable to access a disk when trying to read the data file during the automatic data report generation at midnight. When a read error occurred, the computer was caught in a continuous loop trying to access the disk until the computer was manually reset by the CEM operator and the CEMS operating program rebooted.

The reason for the read errors was most likely the result of high levels of dust in the CEMS rooms. Dust particles tend to scratch the disk surface which often prevents the disk head from accessing a file. This was an ongoing problem despite the regular cleaning of disk heads and air conditioning filters.

Computer operating system problems took the form of operating system errors caused by inadvertent modem operation or due to undetermined problems in the computer operating system. These system errors occurred when a computer instruction caused internal operating control to be transferred to a nonexistent or illegitimate memory location. The net effect was suspension of normal automatic CEMS operations and data acquisition.

Inadvertent modem operation was due to outside parties mistakenly dialing the CEMS modem number. The other operating system problem while undetermined could have been due to read errors when the computer disk operating system software (CDOS) was booted in prior to booting in the CEMS operating software. Again, these read errors could have been a result of dust particles scratching the disk surface creating software read/write errors.

Modem operation was also a problem when remotely accessing the CEMS for status checks. Often when terminating modem operation, a system error would result, requiring the operator to return to the site to restart the CEMS.

Software problems were also experienced in the form of erroneous periods of data acquisition during which all analyzers and conditioning system were working properly. The periods of invalid data were the results of incorrectly calculated emissions data or 3-point calibration factor calculations. The basis for these problems were again thought to be due to errors in the CEMS operating software from dust scratches on the operating disk which created errors in the actual program text stored on the disk. This problem usually corrected itself with the rebooting of a new CEMS operating software disk. The data acquired during these times would not be salvageable even with the existence of a data file editing and correction program.

Computer hardware problems consisted of the failure of the computer disk drive and computer related hardware, the auxilliary control boards electronic relays by which the CEMS was controlled. When the disk drive failed the CEMS operations were terminated. Electronic relay failure also caused the CEMS to crash when a valve failed to actuate and sample flow was interupted. Most of the relay failures occurred during the month of July 1981 when the CEMS room air conditioners failed and CEMS room temperatures were at the operating

limits of the computer system and the electronic relays. The relay failures ultimately were traced to the failure of the auxilliary control board power supply which necessitated a site visit by a KVB technician for replacement.

Downtime Summary--

The monthly summary of CEMS downtime is presented in Table 23. The downtime has been broken into the separate system areas problems and presented accordingly. The downtime results represent downtime when Unit 6 was in operation and include both actual periods when the entire CEMS was not operational and periods when the CEMS was operational but inlet or outlet data were invalidated due to analyzer or conditioning system problems.

- Inlet Monitoring System Downtime--Conditioning system problems were the major causes of inlet monitoring downtime. The major problems were probe blockage and corrosion of fittings and hardware which caused system leaks. The month of December 1981 contained almost half of the conditioning system problems due to cold weather related problem in the form of increased probe blockage and frozen CEMS exhaust lines; and, CEMS restart problems in the form of inlet conditioning system operational problems. These problems were never fully understood but were thought to be due to valve operating problems which crashed the CEMS due to sample flow interuption.

  For the initial period of January 1982, downtime was an extension of December problems in form of frozen CEMS exhaust lines. In May and August 1982, conditioning system problems peaked again due a corrosion leak in an inlet sampling probes in May and in August due to conditioning system problems as a result of read errors and computer operating system problems.

- Outlet Monitor System--Conditioning system problems were the major sources of outlet CEMS downtime, but were limited to primarily the months of December 1981 and January 1982, as with the inlet problems.

  For the outlet monitor system, analyzer problems were a major source of downtime, specifically with the NO_x analyzer. The NO_x analyzer experienced two major periods of operational problems, December 1981 and March 1982. The December problems were indirectly a result of outlet conditioning systems problems, when the internal capillaries and NO_x-NO converter became clogged due to moisture in the sample lines. The March 1982 period was due to the vacuum pump being down and delays from the pump manufacturer in getting the necessary spare parts shipped. A spare pump was not on hand due to the high replacement cost.

- Computer System--Computer system problems were responsible for a large amount of CEMS downtime. Read errors, operating system and hardware problems were the major sources of downtime.

TABLE 23. MONTHLY CEMS DOWNTIME--INVALID DATA SUMMARY

Month	Unit No. 6 Uptime	Hourly CEMS Downtime - Invalid Data, Unit 6 Operational															
		Inlet Monitor System					Outlet Monitor System						Computer System				
		CS	SO_2	O_2	S	OT	CS	SO_2	O_2	NO_x	S	OT	R	OS	S	H	OPS
1981																	
June	648	20	-	9	17	-	-	-	33	-	-	-	14	12	-	-	3
July	528	5	-	-	47	-	-	-	-	-	-	9	-	15	20	143	5
Aug	591	-	-	-	8	12	-	-	-	34	-	12	-	-	-	6	11
Sept	271	-	-	-	-	-	-	-	36	-	-	-	-	8	-	-	-
Dec	552	220	-	-	-	-	109	28	-	215	-	-	90	-	-	-	-
1982																	
Jan	573	58	-	-	-	-	58	17	-	17	-	-	-	-	-	28	3
Feb	409	28	-	-	-	-	-	-	-	48	-	-	-	41	-	-	3
Mar	676	32	9	-	-	-	32	-	-	425	-	-	18	-	-	-	4
April	454	-	-	-	-	11	-	-	-	-	-	-	24	-	-	-	-
May	182	48	-	-	-	-	-	-	-	-	-	-	20	56	-	-	-
June	348	10	-	24	-	-	-	-	-	-	-	-	40	-	-	-	6
July	509	-	-	-	-	-	-	-	-	10	-	11	2	4	-	-	13
Aug	560	96	-	-	-	-	36	-	-	87	-	-	18	-	-	-	-
Totals		517	9	24	72	23	235	45	69	836	0	32	226	136	20	177	48

Key: Inlet and Outlet Monitor Systems

CS = Conditioning System Problem
SO_2, O_2, NO_x = Analyzer Problems
S = Operating Software Problem
OT = Operator Related Problem

Computer System

R = Read Error
OS = Operating System Problem
S = Operating Software Problem
H = Hardware Problem
OPS = Daily Operating

Read errors and operating system problems were experienced throughout the program duration while most of the hardware downtime was experienced in July of 1981, in the form of auxillary control board problems.

PROGRAM COST EVALUATION

The economic impact of continuous monitoring regulations is an area of concern for the source as well as the lawmaker. Although an assessment of economic variables was not one of the primary objectives of this program, some interesting cost information is available. The cost data presented are based solely on the actual costs associated with the Conesville program. The applicability of these costs to other utilities installations is indeterminate at this time. It is anticipated that proper use of the experience gained in this program would significantly reduce certain costs if site-specific variables are taken into consideration.

The utility operator experiences two cost categories in fulfilling the Subpart Da reporting requirements. Initially, major capital expenditures are made in purchasing, installing and certifying a monitoring system. Subsequently, ongoing costs result from routine operation, maintenance and data reporting.

Similarly, the Conesville program was conducted to simulate the monitoring and reporting process. Two of the segments simulated the utility procurement stage and the second, the routine operation, maintenance and reporting process.

Phase II--CEMS Procurement

The CEMS procurement and setup process includes all costs from site preparation to completion of the initial certification tests which marks the acceptance of the system and the beginning of routine monitoring. This initial cost is broken down into the following individual costs:

- Site Preparation
- Continuous Monitor System Procurement
- Vendor Installation
- Startup and Training
- Certification Tests

Figure 25 presents a pie-chart breakdown of the "premonitoring" costs associated with the Conesville CEMS. The purchase price for the system totalled $181,000 delivered to the test site. Prior to installation, $31,030 were spent to build a temperature controlled monitor room, and to route electrical wiring and sample line. These preparations were conducted by a

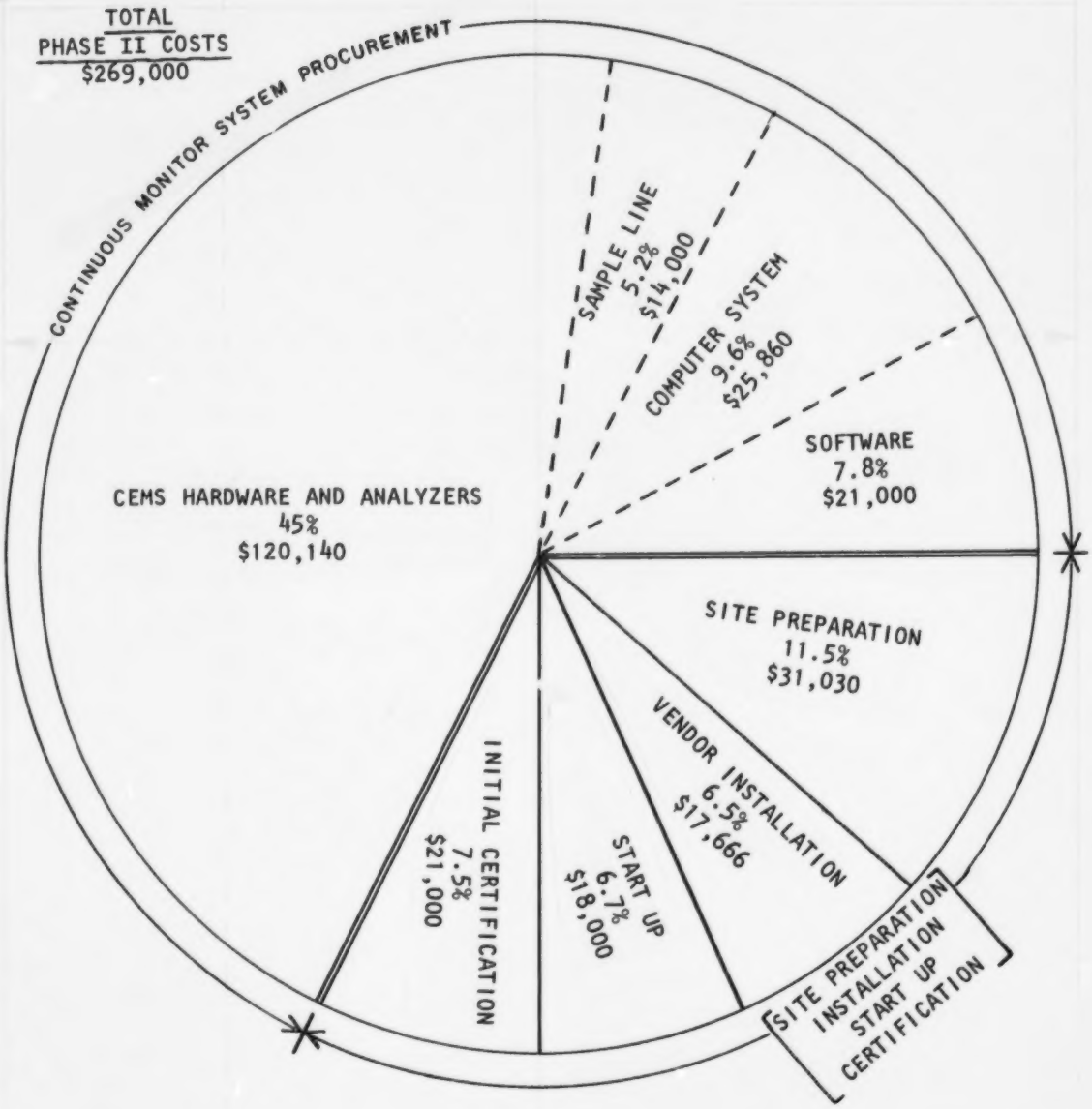


Figure 25. Phase II relative cost summary.

local area contractor. Final installation, startup and checkout was conducted by the vendor and accounts for costs of slightly less than $35,000. Following startup and conditioning, the certification tests were conducted by GCA at a cost of $21,000.

Site Preparation

Because of the lack of suitable facilities in which to locate the monitor system and computer, a complete monitor room was constructed at a cost of $31,030. The room was constructed by an outside contractor and included independent air conditioning and heating units to maintain the room environment at optimal conditions for computer and CEMS operation. In addition, electrical hookups, conduit routing, process signal hookups and sample line installation costs were included. The two CEMS hardware cabinets were also installed. This required the rental of a mobile crane in order to hoist the equipment to the monitor room location.

Figure 25 also shows a cost breakdown for the major CEM system components. The major costs were associated with the analyzers and conditioning hardware. These costs (including heat traced line) totaled $134,120. Computer related hardware and software packages comprised the remaining cost of $46,860.

The system breakdown can also be used to illustrated cost difference between a manual versus an automated system. Approximately $135,000 would be spent for a manually operated three location monitoring system.

Vendor installation involved the onsite fabrication and hookup of the system. This cost was in addition to the system purchase cost. Again this cost remained fixed even with the additional time required for corrections and modifications to the system prior to the initial certification tests. These modifications required additional vendor site visits.

Initial Certification Test--

The initial certification test costs included manpower costs, travel costs, and material costs for performing the 168 hour conditioning period and initial performance specifications tests. In addition, this included the cost of performing initial stratification tests at monitor sample probe locations prior to the initial conduct of the Performance Specification Tests.

Phase III--One Year Field Demonstration

The One Year Field Demonstration cost is divided into the following separate areas:

- CEMS Operations
- Quality Assurance
- Research and Development

The relative costs presented in Figure 26 include all material and manpower costs directly applicable to field demonstration monitor operations. Research and Development costs are for materials only. To make these costs more comparative to utility costs for actual CEMS operation, the associated environmental contractor costs have not been included. These associated costs would be for travel and living costs for maintaining the CEMS technician onsite fulltime and for the performance specifications test and relative accuracy test crews. Based on these conditions, it can be seen in Figure 24 that costs for CEMS operations and Quality Assurance were nearly equal for the field demonstration phase. A more detailed explanation and breakdown of these costs follows.

CEMS Operations--

The CEMS operational costs presented in this section comprise both material and manpower costs for CEMS operation during Phase III. The operating costs are discussed for the following three areas:

- Routine Maintenance
- Nonroutine Maintenance
- Daily Operations

Figure 27 shows a pie chart breakdown of the Phase III operational costs experienced at Conesville and Table 24 provides a further breakdown of the labor requirements. The Phase III labor hours totalled 915 hours (17 hrs/week) for daily operations, 327 hours (27 hrs/month) for non-routine maintenance and 196 hours (16 hrs/month) for preventive maintenance. Non-routine materials costs totalled $2,769 and routine expendible materials costs totalled $2,869. One should note that the non-routine material costs are biased low due to the fact that many of the replacement parts were supplied under warranty free of charge. Manpower cost for nonroutine maintenance and routine maintenance were 18 percent and 11 percent, respectively, of the total operations level of effort. This manpower difference is due to the more intensive manpower effort required to troubleshoot the CEMS and isolate problems. The relatively low routine maintenance manpower costs would substantiate the fact that the CEMS was close to meeting the low manpower requirement design objective in terms of routine maintenance.

Expendible materials for the Sample Conditioning System consisted of limited service life components requiring replacement due to normal wear experienced from continuous use. Those components consisted of sample pump diaphrams and fiapper valves, hot box air valve diaphrams and primary and secondary particulate filter elements. Analyzer expendibles were limited to the NO_x analyzer and included capillaries for sample, ozone and bypass flows, vacuum pump oil, pump gaskets and ozone generator dessicant. Materials required for computer operation consisted of floppy diskettes, disk cleaning kits and printer paper and ribbon.

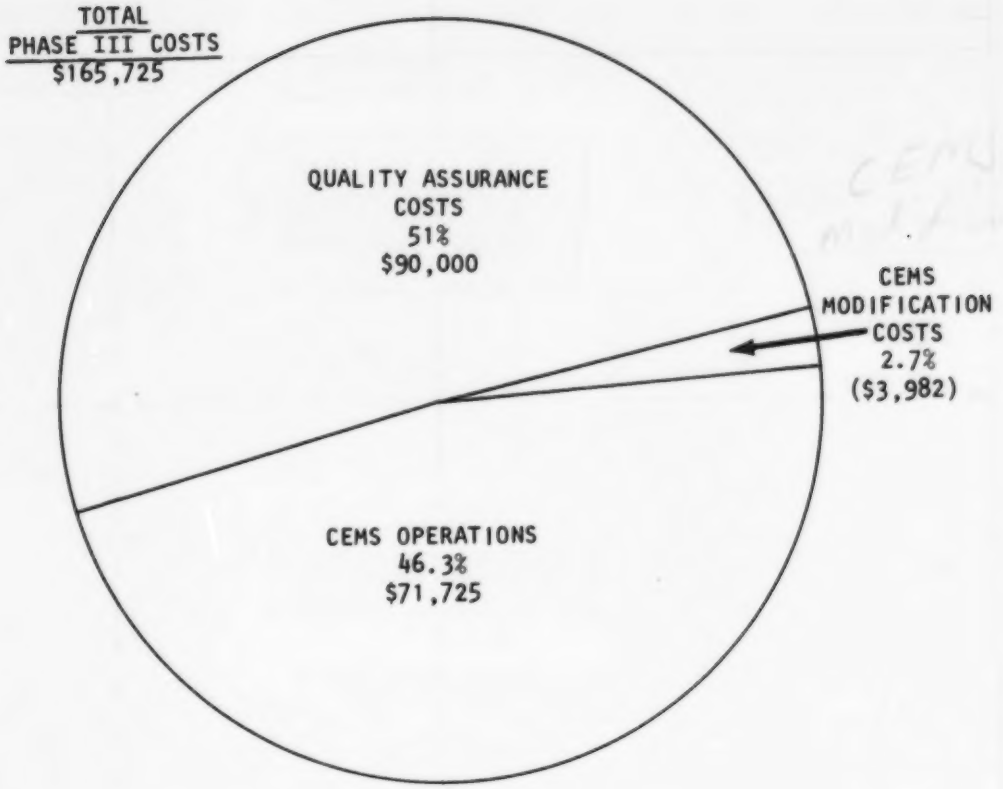


Figure 26. Phase III overall relative costs.

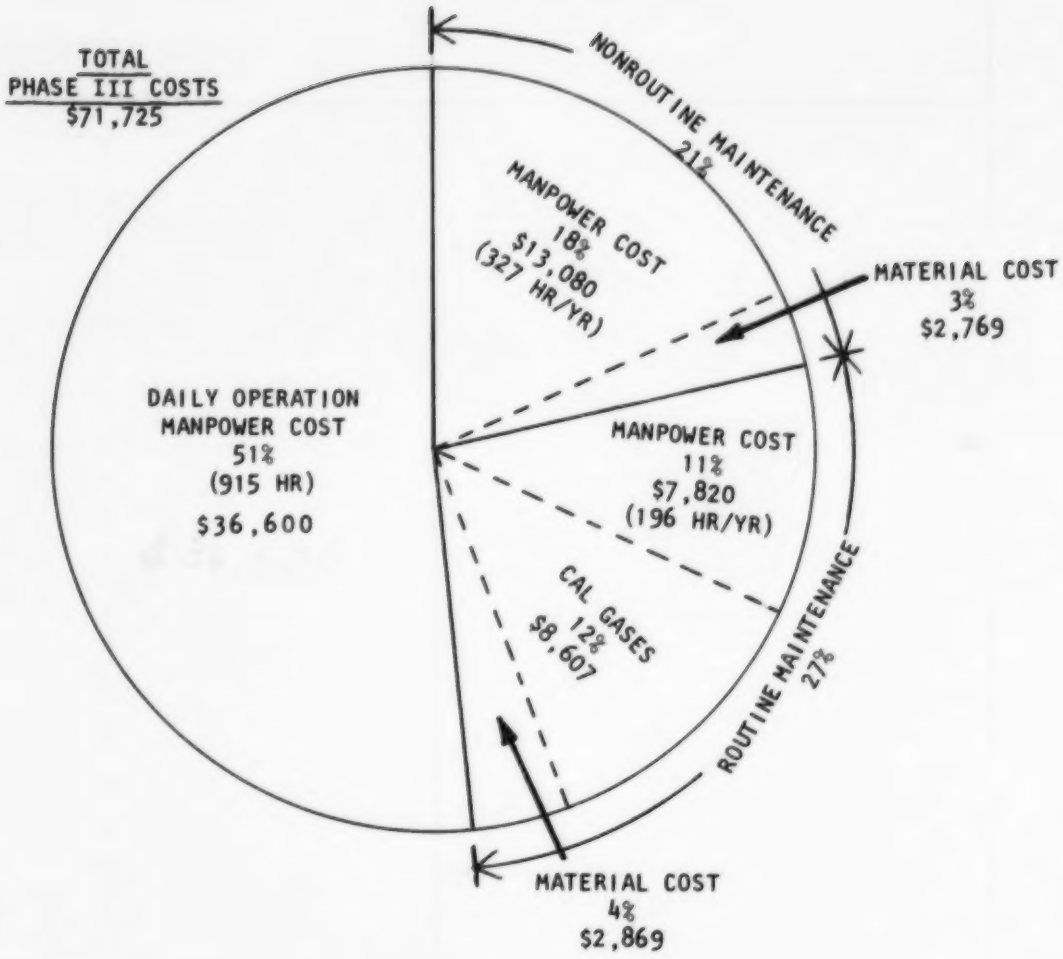


Figure 27. Phase III relative CEMS operational costs.

TABLE 24. CEMS OPERATION MANHOUR REQUIREMENT SUMMARY

	CEMS Maintenance Summary									
	Conditioning System		Analyzers		Computer		Total		Daily Operations	Total Manhour Requirements
	NR	R	NR	R	NR	R	NR	R		
Total Hours	242	62	60	118	25	16	327	196	915	1437
% Total	17%	4%	4%	8%	2%	1%	23%	14%	64%	---
Weekly Average Hours	4.5	1	1	2.2	0.5	0.3	6	4	17	27

NR = Nonroutine Maintenance
R = Routine Maintenance

Nonroutine maintenance costs included material costs incurred for replacing analyzer and sample conditioning system components and manpower costs associated with CEMS troubleshooting and component replacement. Another cost included under nonroutine maintenance were costs incurred for CEMS room air conditioner service repair which required the services of an outside contractor.

In addition to material costs for routine and nonroutine maintenance, calibration gases comprised a major material cost incurred for CEMS operations and represents the largest single expendable material expense shown in Figure 27. This large expense is considered normal, for any continuous monitor system equipped with automatically controlled calibration systems such as the one used at Conesville. Since analyzer drift and analyzer calibration factors are automatically calculated, it is estimated that over half of these calibration gas costs would be recovered from manpower costs saved if manual daily analyzer drift checks and calibrations were performed.

It should be noted that the relative calibration gas cost have included not only the actual cost of the calibration gas but also included freight costs for transporting gas cylinders from and to the manufacturer and monthly gas cylinder rental charges.

The last area of material costs should be mentioned briefly and can be classified as Warranty Replacement costs. These are estimated costs for all the CEMS components replaced by the vendor without charge in fulfillment of the CEMS Vendor Warranty. Some of the major components replaced included: the computer disk drive, disk drive controller PC board, lamp sources for the DuPont analyzers, zirconium oxide cells for the O_2 analyzers, various solenoid valves and pressure switches and an inlet sampling probe. These components were determined by the vendor to have failed before their "expected" service life had expired. This last cost area was included to provide a better understanding of actual component replacement costs had the CEMS not been under warranty. This warranty period lasted one year from the completion of the initial certification tests.

Quality Assurance Costs

Quality Assurance Costs for the program were incurred in the following major areas:

- Performance Specification Tests
- Quarterly Relative Accuracy Audits
- Precision Estimate Reporting
- Stratification Tests

Performance specification tests, relative accuracy audits (RAA) and stratification test costs were figured as if conducted by an "outside" contractor; that is travel and living costs for field test crews were included

in costs. This was done to enable a better comparison between the actual costs and cost projections for "inhouse" utility performed PSTs, RAAs and stratification tests.

The Phase III quality assurance costs are shown in Figure 28 and include the labor, material and travel costs associated with the testing. Performance specifications tests and relative accuracy audits represent costs totalling $75,060 or 80 percent of the total quality assurance expenditures. The remaining 20 percent of the quality assurance budget was directed at stratification testing and the estimate of system precision.

Performance Specifications Tests--

Performance Specifications Tests were conducted at the beginning and at the completion of the Routine Monitoring Phase of the program. The initial Performance Specification Test consisted of the full set of nine relative accuracy tests, 2 and 24 hour drift tests, and calibration error tests on all analyzers for each CEMS sampling locations.

Relative accuracy tests were conducted simultaneously at the two inlet locations utilizing two sets of manual methods test equipment while outlet relative accuracy tests were performed separately at a different time. This same procedure was followed for the Relative Accuracy Audits.

Included in the costs associated with the initial Performance Specification was the cost to perform Stratification Tests to verify CEMS probe placement. This cost normally would be included in Performance Specification Test costs on a system where monitor probe placement does not meet the siting criteria as delineated in Performance Specifications 2 and 3.

Relative Accuracy Audits--

Relative Accuracy Audits consisting of six reference method test runs at each sampling location were conducted twice during the program. In addition, a third Relative Accuracy Audit was performed and consisted of a complete set of nine relative accuracy tests at the outlet location. Due to analyzer problems, a set of only seven relative accuracy tests were performed at the inlet location. The overall costs for Relative Accuracy Audits includes all three of these test sets.

Precision Estimate Reporting--

The precision estimate reporting costs were straight manpower costs for manually performing the precision estimate calculations for all analyzers. Precision estimates, while not reported on a quarterly basis during the program, were calculated for the entire routine monitoring phase of the program.

Stratification Test

Stratification test costs included the cost associated with the additional stratification tests conducted during relative accuracy audits. These additional tests while not required under proposed Appendix F were conducted at the outlet location only as part of a related program study to

PIE CHART TOTAL

$90,000

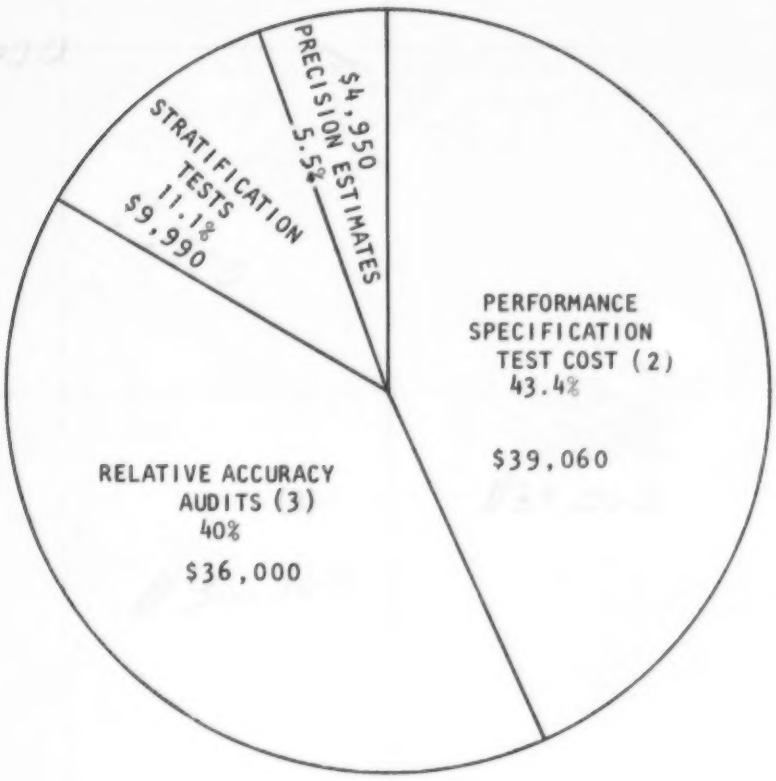


Figure 28. Phase III quality assurance costs.

characterize the spatial variatiability of SO_2 emissions in the duct at the outlet CEMS sampling location with respect to boiler load and scrubber module and bypass duct gas flows rates.

CEMS Modification Costs

CEMS modifications made during the program involved the improvements to the CEMS to increase the performance and reliability of the sample conditioning system, analyzers, support equipment and computer hardware and software. These were made in an effort to correct problems and increase the reliability of the CEMS and its subsystems. Changes were made throughout the duration of Phases II and III.

This cost is the most difficult to definitize and summarize for several reasons.

- Development and installation of many of the modifications were performed by the vendor at no additional cost increase. This included both material and manpower costs. This would also include additional manpower for software development.

- CEMS operator manpower requirements for troubleshooting to identify and correct some of the CEMS problems without vendor assistance were absorbed into nonroutine maintenance costs due to the nature of the work involved.

- CEMS operator manpower expenditures for assisting in vendor installation of the modifications are not known.

Because of the uncertainty involved in defining the overall program costs for modifications, real costs can only be presented for the additional hardware involved in making and implementing modifications to the CEMS during the program. The estimated cost of the hardware involved in making CEMS modifications in relation to the CEMS purchase cost is estimated at 2.2 percent of the CEMS purchase cost or approximately $4,000.

Projected Subpart Da Utility Costs

Costs to the utility for monitoring under Subpart Da and Draft Appendix F requirements are discussed and projected in terms of manpower requirements and material expenditures. Manpower requirements and material expenditures are projected in terms of both annual and quarterly costs. These projections are derived using the manpower requirements and material cost performance of Phase III as the basis. The projections assume that all monitoring operations including performance specification tests and the required Relative Accuracy Audits are performed "in-house," employing utility personnel. Another assumption made is that the source is operated year round with a one month outage period for the normal yearly overhaul.

Manpower and/or material requirements have been broken down into the following areas:

- Daily CEMS Operations
- Routine Maintenance
- Nonroutine Maintenance
- Subpart Da Report Preparation
- Appendix F Requirements
- Performance Specification Tests

The Appendix F requirements include quarterly relative accuracy audits and precision estimate reporting for manpower and the material cost of maintaining the necessary spare parts inventory for CEMS repair and maintenance.

Manpower Projections--

Manpower requirement projections were estimated based on the costs experienced during Phase III. Figure 29 depicts the projected annual Subpart Da labor requirements for each area. Included in the annual projection is the manpower requirement for conducting the initial performance specification tests as this would be included in the first year of a monitoring program following CEMS procurement.

CEMS operations would represent the largest labor requirement comprising close to 900 hours or 40 percent of annual manpower requirements. Daily operation tasks, as in Phase III include: administration, report preparation, logistical support, daily analyzer calibrations and documentation.

Annual routine and nonroutine maintenance manpower outlays total 8 percent and 13 percent respectively; and when combined represent approximately one fifth of the total manpower effort or 520 hours per year. Nonroutine maintenance, by nature, is hard to estimate and is based on Phase III experience. The difference between these two manpower areas is due to the increased effort required for nonroutine maintenance troubleshooting and hardware replacement. Ideally as more experience is gained with CEMS operation in terms of component life, and potential problem development, the routine maintenance effort should increase and nonroutine maintenance effort decrease because problems would be located and corrected before surfacing as a major maintenance effort.

The last major area of annual manpower requirements would be in fulfilling Appendix F quality assurance requirements for quarterly assessment of data accuracy and analyzer precision estimate reporting. Manpower projections in this area are based on performing quarterly relative accuracy

audits (RAAs) only. Manpower requirements for using the alternative method of semiannual relative accuracy audits and semiannual cylinder gas audits (CGAs) have not been projected here because there were no CGAs conducted at Conesville during Phase III.

Overall manpower efforts to meet Draft Appendix F criteria were estimated at 30 percent of the annual manpower expenditures (660 hours), with requirements for the RAAs at 23 percent. The relative RAA manpower effort includes performing in-house sampling and analysis for Methods 3, 6, and 7. Substantial manpower savings for conducting quarterly assessment of data accuracy would probably be realized using semiannual CGAs along with RAAs. CGAs could be performed by a single man in 4 hours. RAAs typically require a 3 man crew and 2 days for sampling and analysis for Methods 3, 6, 7. Approximately 2 days are required for the Method 7 laboratory analysis by a single laboratory technician.

Precision estimate reporting manhour requirements were projected at 120 hours per year or 5 percent of the annual level of effort. This is based on manpower requirements for performing precision estimates during Phase III. Phase III precision estimates were manually calculated from the daily drift check results which typically averaged 10 hours for each month of operation. Manpower requirements for precision estimates could be reduced to nearly zero using a computer and the proper precision estimate software.

Subpart Da report preparation was projected at 100 hours/yr or 4 percent of the annual manpower requirement as shown in Figure 29. This projection assumes totally automatic data acquisition and 30 day rolling average reporting using a computer. This would also include automatic compliance determination computations using the Method 19 procedures when the minimum data capture requirements have not been met. Additionally the projection includes the Data Assessment Report Preparation required by Draft Appendix F.

Material Costs Projections--

Material cost projections are provided, for the normal CEMS operational areas which include nonroutine maintenance, routine maintenance calibration gases and RAA sampling. In addition, two other major material cost areas are introduced, spare parts inventory cost to meet the Appendix F inventory requirements and sampling equipment costs for performing in-house RAAs.

Figure 30 depicts the relative annual material costs for CEMS operations versus the actual CEMS purchase cost. Calibration gas cost represents the largest expendible cost with routine and nonroutine maintenance costs being next in comparison. Nonroutine maintenance costs as stated previously cannot be accurately projected due to the unpredictability of component failure and problem troubleshooting. The 1.5 percent relative cost of nonroutine maintenance does not include major component failure such as a computer disk drive but does include smaller component failures such as solenoid valve, air valve or a SO_2 source lamp failures.

Spare parts inventory costs approach 5 percent and reference method sampling equipment costs are 7 percent of the CEMS purchase cost and represent additional capital investment expenditures beyond the actual CEMS purchase.

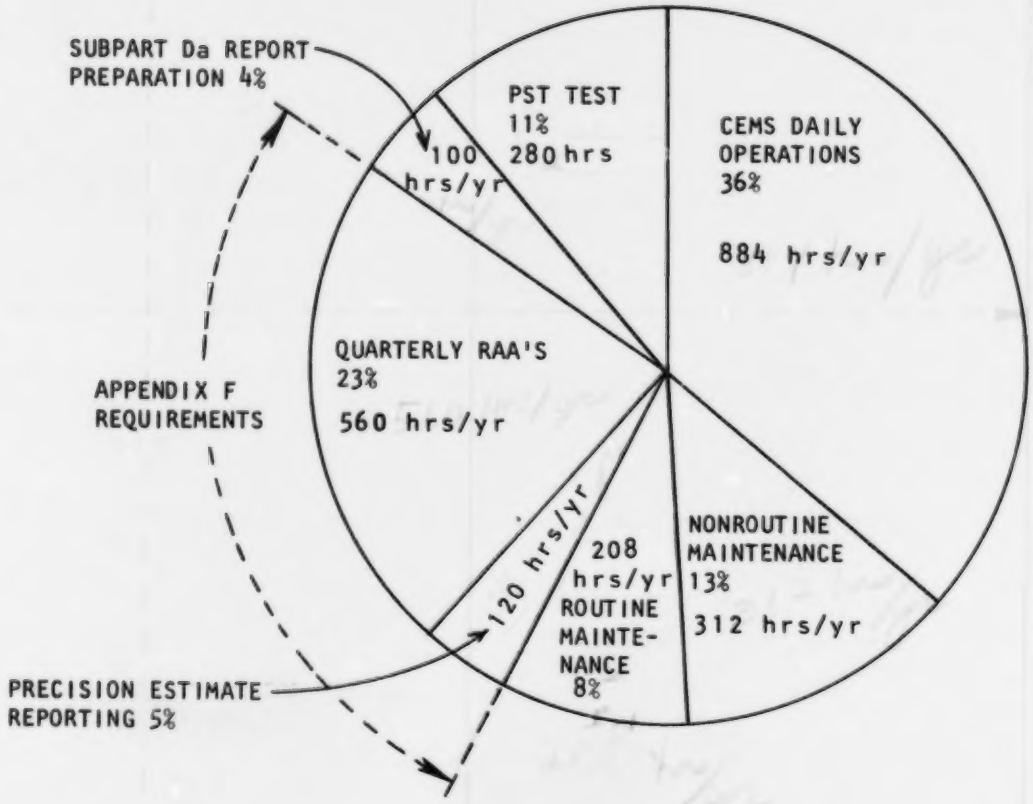
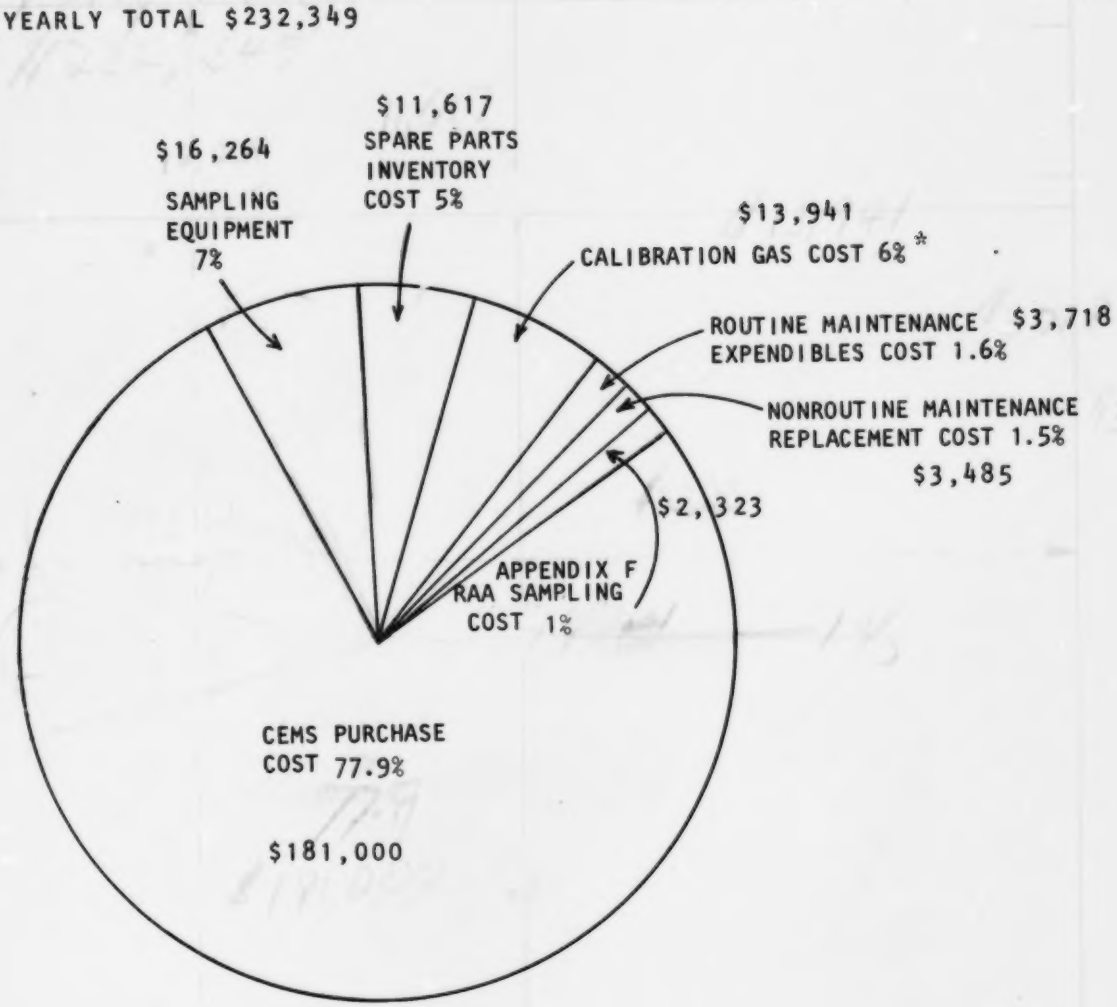


Figure 29. Projected annual utility subpart Da manpower requirements including initial PST test.



*Assumes the use of Protocol 1 certified gases. Yearly cost using analyzed gases would approach $8400.

Figure 30. Estimated utility annual CEMS operating material costs relative to actual CEMS cost.

Spare parts inventory costs include the expense of acquiring and maintaining a complete spare parts inventory for the CEMS subsystems. This cost is based on spare parts recommended for operation of the Conesville CEMS by the vendor and from operational experience gained during this program. Some of the major parts required include:

- Sample Conditioning System Components
  - Hot box air valves
  - Teflon solenoid valves
  - Pressure and vacuum switches
  - Ball valve and actuator
  - Back pressure regulator
  - Spare inlet probe and filter
- Analyzer Components
  - Dupont Analyzer: source lamp, photo multiplier tube, amplifier tube, lamp power supply
  - Thermox Analyzer: RTD, zirconium oxide cell, furnace, temperature control card
  - Thermo Electron Analyzer: vacuum pump
- Computer System
  - Disk controller PC board
  - Electronic relays

This list provides an idea of the extent of the required spare parts inventory for a system such as Conesville. The inventory cost is only for the intial expenditure required and does not include any replacement cost for parts used in performing nonroutine maintenance.